TEST & ALIGNMENT PROCEDURES

FOR

FM SIGNAL GENERATORS

Types: 202B, 202C, 202D,

202E, 202F, 202G

BOONTON RADIO COMPANY

Green Pond Road Rockaway, New Jersey

U. S. A.

MP MASTER

MA24309

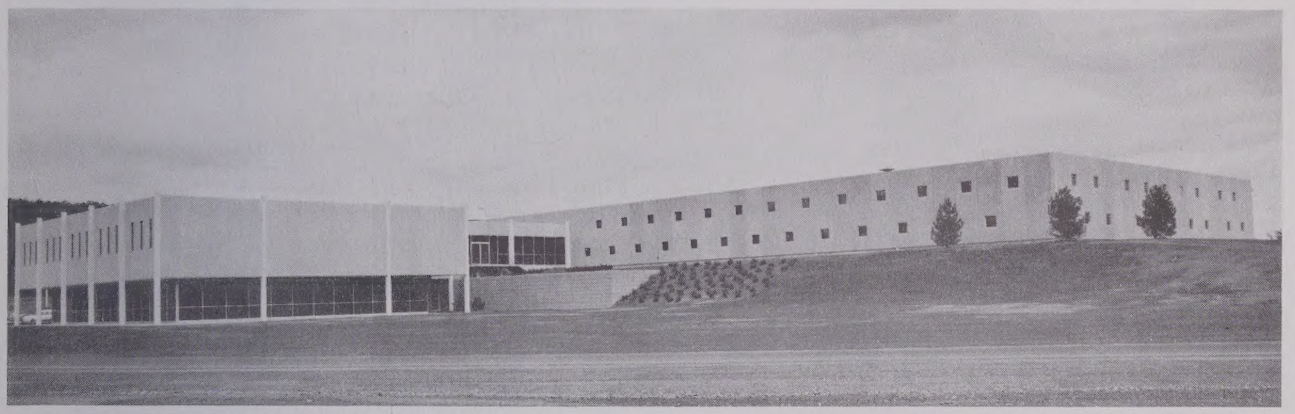
New BRC Plant

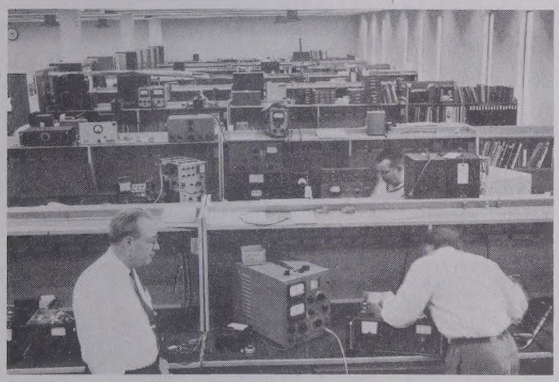
OFFICE

EATING AREA

RECEPTION

DRAFTING





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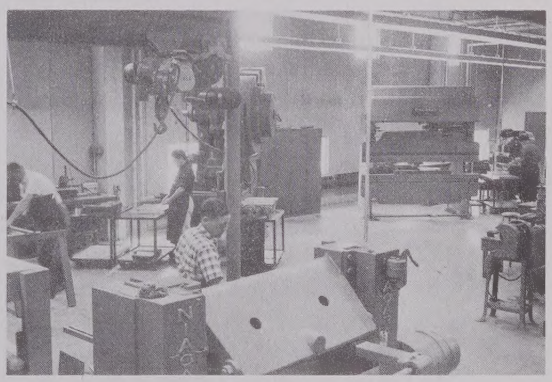

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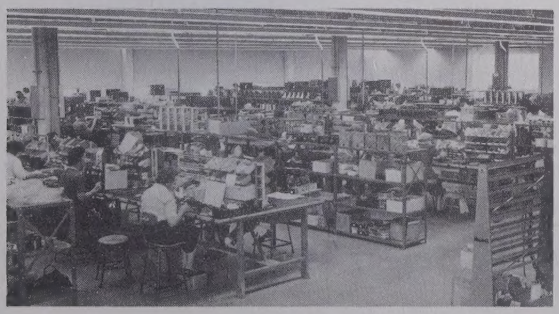

ASSEMBLY

INSPECTION

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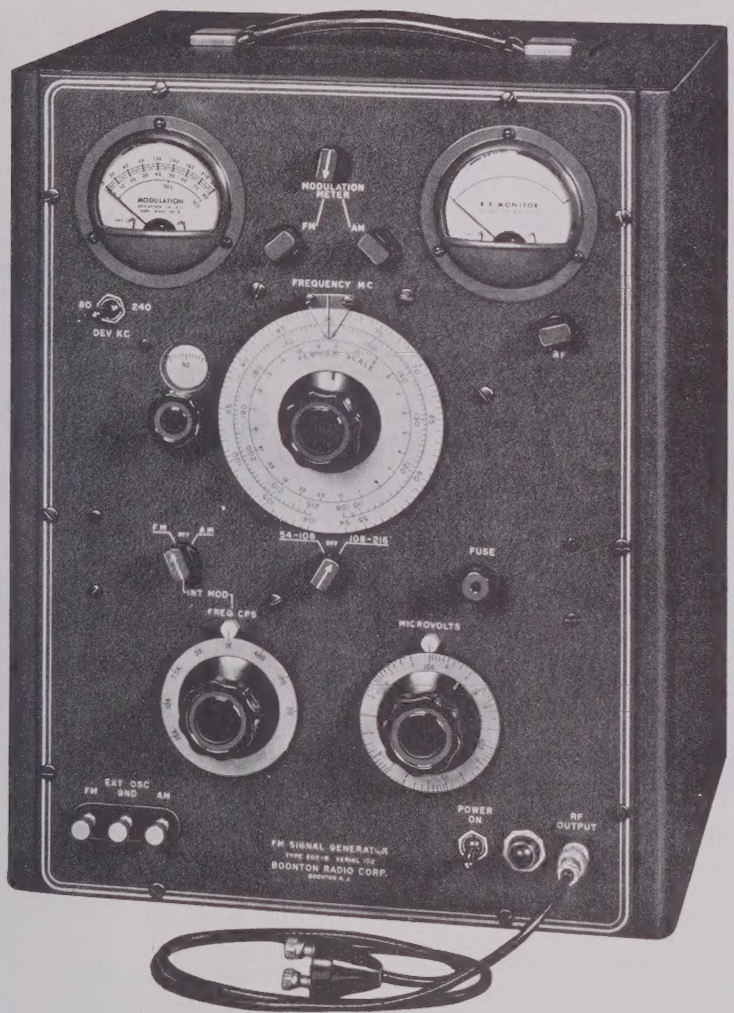
SECTION I

TECHNICAL DATA
AND
SPECIFICATIONS

THE FOLLOWING PAGES CONTAIN THE PUBLISHED "CATALOG SPECIFICATIONS" TO WHICH EACH INSTRUMENT IS GUARANTEED TO OPERATE WHEN IN GOOD REPAIR AND PROPERLY ALIGNED.

EACH INSTRUMENT TYPE (202B THRU 202G) IS REPRESENTED BY PAGES FROM THE APPROPRIATE BRC INSTRUMENT CATALOG. ALL ARE NOW NON-PRODUCTION INSTRUMENTS, HAVING BEEN SUPERSEDED BY THE CURRENT TYPE 202H AND 202J FM SIGNAL GENERATORS.

SIGNAL GENERATOR TYPE 202-B: FM-AM



Frequency Range 54-216 MC

DESCRIPTION

The Type 202-B FM-AM Signal Generator has been developed to meet the needs of engineers engaged in the design of FM and television receivers for operation within the frequency range of from 54 megacycles to 216 megacycles.

This instrument has been proportioned for maximum conservation of laboratory bench space, with frequency dial, modulation and output meters positioned at eyelevel for maximum readability.

An internal audio frequency oscillator provides eight modulation frequencies ranging from 50 cycles to 15 kilocycles, any one of which may be conveniently selected by a rotary type switch for either amplitude or frequency modulation.

An external audio oscillator may be used in place of the internal modulating oscillator or used in conjunction with the internal oscillator to provide AM and FM simultaneously.

Three deviation ranges: 0-24 kc., 0-80 kc., and 0-240 kc. are available for frequency modulation, and amplitude modulation settings may be made at 30% and 50%.

A calibrated piston type of RF attenuator is used, the range of which is 0.1 microvolts to 0.2 volts. Direct settings in microvolts are made by means of the front panel attenuator dial after the output level has been standardized by adjusting the pointer of the output meter to a single calibration line on the meter scale.

The output cable connects at the front panel by means of a BNC type connector, permitting quick detachment and interchangeability with other output cables.

The unit is finished in grey wrinkle enamel with engraved panel and is supplied complete with tubes and standard output cable.

SPECIFICATIONS

RF Range: Frequencies from 54 mc. to 216 mc. are covered in two ranges: 54-108 mc.; and 108-216 mc. By use of the 207-A Univerter, the range is extended to 0.1 to 216 mc. (see page 20).

Main Frequency Dial: The two RF ranges are calibrated directly in megacycles to an accuracy of within ±0.5%. The dial is also divided in 24 equal divisions for use with the vernier frequency dial.

Vernier Frequency Dial: The vernier frequency dial is divided in 100 divisions and is geared to the main dial through a gear train having a 24:1 ratio. The approximate frequency change per vernier division is 26 kc. on the low range and 52 kc. on the high range.

RF Output Voltage: The RF output voltage is continuously variable over a range from 0.1 microvolt to 0.2 volts at the terminals of the output cable. The impedance at the RF output jack, looking into the instrument, is 50 ohms. The output cable has a 50 ohm resistance termination at the terminal end, hence the output impedance of the unit with cable attached is 25 ohms.

Frequency Modulation (Deviation): The FM deviation is continuously variable from zero to 240 kc. The modulation meter is calibrated in three FM ranges (1) zero to 24 kc., (2) zero to 80 kc., and (3) zero to 240 kc. deviation.

Distortion: FM distortion at 75 kc. deviation is less than 2% when modulated with the internal AF oscillator or an external AF oscillator having 0.5% distortion or less.

At 50% amplitude modulation the distortion is about 5% using the internal AF oscillator and decreases as the modulation percentage is reduced. An external AF oscillator may be employed for amplitude modulation if desired.

Fidelity Characteristics: The deviation sensitivity of the FM modulation system as a function of frequency is flat within 0.5 db from 30 cps to 15 kc. The amplitude modulation system is essentially flat from 100 cps to 10 kc. and is flat within ±0.5 db from 30 cps to 15 kc.

Amplitude Modulation: The modulation meter is calibrated at 30% and 50% amplitude modulation. AM is continuously variable from zero to 50%.

Modulation Controls: Separate potentiometers are provided for continuous control of FM and AM levels.

Modulating Oscillator: The internal AF oscillator may be switched to provide either frequency or amplitude modulation; it may also be switched off. External binding posts permit the use of an external AF oscillator for either FM or AM. Both internal and external AF oscillators may be used simultaneously, thus providing either FM or AM at two modulation frequencies simultaneously, or simultaneous FM and AM; the external oscillator is to be used for FM in the latter case.

The internal AF oscillator provides eight fixed frequencies which may be selected by a rotary type switch — 50, 100, 400 cycles and 1, 5, 7.5, 10 and 15 kilocycles, accurate to within 5%. The output voltage of the internal AF oscillator is available at the external binding posts for synchronizing or other purposes.

Spurious RF Output: All spurious RF output voltages are at least 30 db below the desired fundamental. The RF leakage is very low.

Accessories:

Furnished: 501-B Output Cable

Available: 207-A Univerter (for extending frequency range down to 100 kc.
Miscellaneous Pads & Cables

Tubes:

1 — 6AU6
1 — 6V6GT/G
1 — 544A (Selected 6C4)
1 — 543B (Selected 6AK5)
2 — 543A (Selected 6AK5)
1 — 5Y3GT/G
1 — 6H-6
1 — 545-A (Selected 3S6/5)
1 — OD3/VR-150

Power Supply: The power supply is self-contained in the instrument for use on 50-60 cycles, 105-125 volts. Internal regulation is provided so that the frequency does not change by more than 0.05% for line voltage variations from 105-125 volts. The power consumption is 65 watts. Instrument for 230 volt operation available at extra charge.

Size: Height 17", Width 13½", depth 11½".

Weight: 35 lbs. net.
90 lbs. gross packed for export.
47 lbs. gross packed for domestic.
44 lbs. legal weight packed for export.

SIGNAL GENERATOR TYPE 202-C: FM-AM

Frequency Range 54-216 MC

DESCRIPTION

The Type 202-C FM-AM Signal Generator is particularly well adapted for testing and evaluating mobile radio receiving equipment and other systems employing narrow band frequency modulation within the range from 54-216 mc.

This instrument is very similar in design and appearance to the Type 202-BFM-AM Signal Generator except that an electronic tuning feature has been added which permits continuous, fine adjustment of the carrier frequency either side of center to a maximum of 10 kc. in the 54-108 mc. range and 20 kc. in the 108-216 mc. range. An incremental frequency switch has also been provided which enables the operator to change the carrier frequency by accurately determined increments, thus enabling selectivity measurements to be accomplished with rapidity and ease.

Seven audio frequencies ranging from 50 cycles to 10 kilocycles are available from the internal audio oscillator for either amplitude or frequency modulation. In addition, a 60 kilocycle modulation frequency may be selected which permits the accuracy of the incremental frequency calibration to be checked from time to time.

In order to reduce the noise level of the carrier to an absolute minimum the power supply and all associated circuits have been incorporated in a completely separate unit thus eliminating stray magnetic fields, vibration, etc. The unit is attractively finished in grey wrinkle enamel and is supplied complete with external power supply, tubes, and output cable.

SPECIFICATIONS

RF Range: Overall frequency coverage 54 to 216 megacycles in two ranges: 54-108 megacycles and 108-216 megacycles, accurate to within ±0.5% after a warm-up period of one hour. The main frequency dial is also calibrated in 24 equal divisions for use with the vernier frequency dial.

RF Output Voltage: The maximum open circuit output voltage from the BNC type RF output jack at the front panel is about 0.4 volt. With the standard output cable (type 501-B) attached, the maximum calibrated output voltage at the cable terminals is 0.2 volt nominal. When the RF monitor meter is set to the red calibration line and the standard output cable attached, the RF output attenuator is direct reading in microvolts and continuously adjustable from 0.1 microvolt to 0.2 volt. The approximate accuracy is ±10%.

RF Output Impedance: The RF output impedance of the signal generator as seen looking in at the BNC type front panel connector is 50 ohms. With the standard output cable attached, the RF output impedance as seen looking in at the output cable terminals is 25 ohms.

Frequency Modulation: Three frequency deviation ranges, 0-24 kc., 0-80 kc., and 0-240 kc. are provided, each continuously adjustable. Calibrated frequency increments are 1 kc. on the 24 kc. range, 5 kc. on the 80 kc. range, and 10 kc. on the 240 kc. range.

FM Distortion: The overall FM distortion at 75 kc. is less than 2% and at 240 kc. less than 10%.
These distortion percentages apply when the front panel fine tuning control is set midway in rotation and the △F control at zero electronic deviation, or when the sum of the fixed deviation and modulation deviation do not exceed the stated deviations.

Fidelity Characteristics: The deviation sensitivity of the FM modulation system is flat to approximately 1 db from 30 cps to 30 kc. The amplitude modulation system is flat within ±1 db from 30 cps to 30 kc.

Amplitude Modulation: Amplitude modulation is available over the range from 0-50% with meter calibration points provided at 30% and 50% modulation.

AM Distortion: Overall distortion is less than 5% at 30% modulation, and less than 8% at 50% modulation.

Simultaneous FM and AM: The 202-C FM Signal Generator in combination with an external low distortion audio oscillator, may be used for this purpose provided that the audio oscillator is capable of developing approximately 5 volts across a 1500 ohm load, the FM requirement for 240 kc. deviation. In use the external audio oscillator is connected to the FM external binding posts, the modulation selector switch set to AM, and the levels of each type of modulation independently set on the modulation meter, by operation of the modulation meter switch, FM deviation control, and amplitude modulation control.

Spurious RF Output: All spurious RF output voltages are at least 30 db below the desired fundamental.

Signal-To-Noise Ratio: The signal-to-noise ratio referred to the level established by 10 kc. deviation is better than 60 db in a quiet location. Where considerable noise and vibration are present, the ratio may drop to 55 db.

Internal AF Oscillator: The internal AF oscillator may be switched to provide either frequency or amplitude modulation; it may also be switched off.
The internal AF oscillator provides eight frequencies which may be selected by a rotary switch—50, 100, and 400 cycles, 1, 5, 7.5, and 10 kc., and 60 kc. for calibrating the Incremental Frequency Range Switch. Frequency accuracy is within 5% on all but 60 kc., where accuracy is ±2%. The output of the internal oscillator is available (at the external binding posts) for synchronizing or other applications if desired. Approximately 5V. on the FM posts and 50V. on the AM posts are available.

Special Features: Incremental Frequency Range: The △F switch permits tuning in frequency increments of ±5, ±10, ±15, ±20, ±25, ±30, ±50, ±60 kc. in the 108 to 216 mc. range — half of these values in the 54 to 108 mc. range. The relative accuracy of the increments is ±1.5%. The overall accuracy is dependent on the accuracy of the 60 kc. modulating frequency. When the 60 kc. accuracy is ±2% or better, the overall accuracy is ±6% at the carrier frequency checked.

Fine Tuning Range: The fine tuning control permits continuous tuning over a range of approximately ±20 kc. in the 108 to 216 mc. range, and ±10 kc. in the 54-108 mc. range. No calibration is provided.

Accessories:
Furnished:
202CP1 Power Supply
501-B Output Cable
Available:
207-A Univerter (for extending frequency range down to 100 kc.)
Miscellaneous Pads & Cables

Tube Complement:

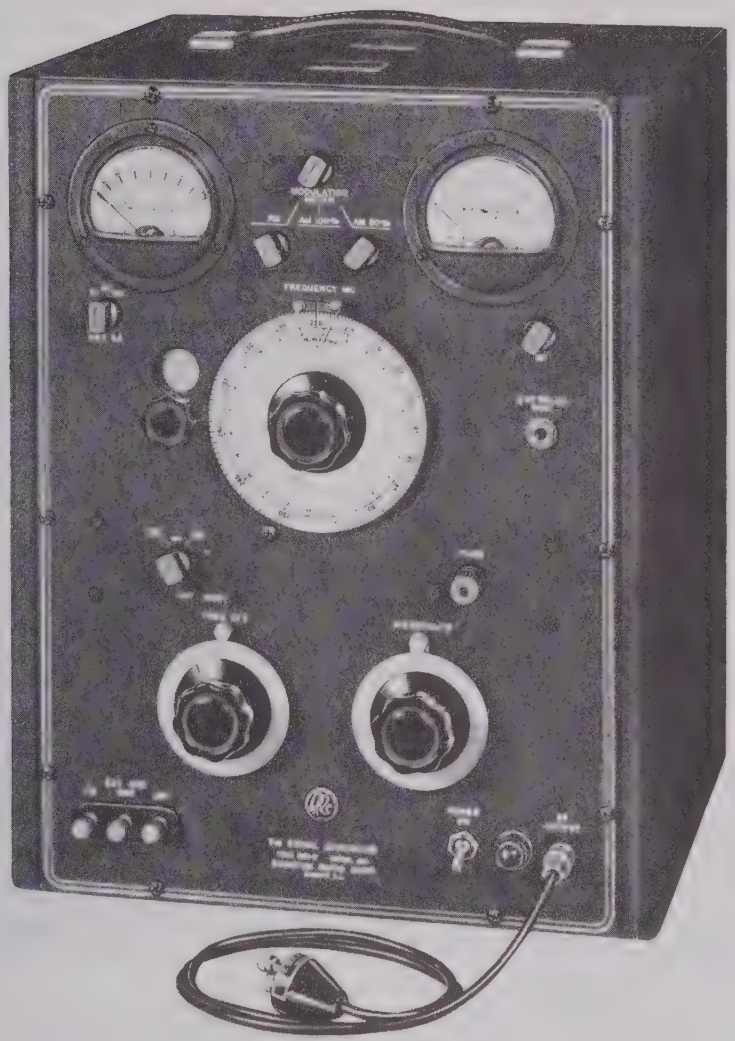
1—6AU6	2—543A (Selected 6AK5)
1—6V6GT/G	1—5Y3GT/G
1—544A (Selected 6C4)	1—6H-6
1—543B (Selected 6AK5)	1—545A (Selected 3S6/5)
	1—OD3/VR-150

Power Supply — 202-CP1: A separate external power supply furnishes all the dc potentials required for the operation of the 202-C Signal Generator. Output voltages are 250, 150, 6.9 and 6.5 volts d.c., with ripple contents averaging 15 millivolts, less than 1 millivolt, 50 millivolts, and 50 millivolts, respectively.

Size:
202-C Height 17", Width 13½", Depth 11½".
202-CP1 Height 8¼", Width 16¼", Depth 8".

Weight: (Signal Generator and Power Supply):
52 lbs. net.
125 lbs. gross packed for export.
65 lbs. gross packed for domestic.
57 lbs. weight packed for export.

SIGNAL GENERATOR TYPE 202-D: FM-AM



Frequency Range 175-250 MC

DESCRIPTION

The Type 202-D Signal Generator is a precise and reliable instrument well suited to the specialized requirements of telemetering engineers for rapidly analyzing overall system performance. It is very similar in design and appearance to the 202-B FM-AM Signal Generator but it has a frequency coverage of from 175-250 mc., provided in a single range.

An internal audio frequency oscillator furnishes eight modulation frequencies ranging from 50 cycles to 15 kilocycles, any one of which may be selected by a rotary type switch for either amplitude or frequency modulation.

Three deviation ranges: 0-24 kc., 0-80 kc., and 0-240 kc. are available for frequency modulation, and amplitude modulation, settings may be made at 30% and 50%. By means of an external audio oscillator, amplitude modulation to substantially 100% may also be obtained, and a front panel jack permits the connection of an external modulation source for pulse and square wave modulation.

The Type 202-D Signal Generator is finished in grey wrinkle enamel with engraved panel and is supplied complete with tubes and standard Type 501-B output cable.

SPECIFICATIONS

RF Range: Overall frequency coverage 175-250 megacycles in one range, accurate to ±0.5% after a warm-up period of one hour. The main frequency dial is also calibrated in 24 equal divisions for use with the vernier frequency dial.

RF Output Voltage: The maximum open circuit output voltage from the BNC type RF output jack at the front panel is about 0.4 volt. With the standard output cable (type 501-B) attached, the maximum calibrated output voltage at the cable terminals is 0.2 volt nominal. When the RF monitor meter is set to the red calibration line and the standard output cable attached, the RF output attenuator is direct reading in microvolts and continuously adjustable from 0.1 microvolt to 0.2 volt.

RF Output Impedances: The RF output impedance of the signal generator as seen looking in at the BNC type front panel connector is 50 ohms. With the standard output cable attached, the RF output impedance as seen looking in at the output cable terminals is 25 ohms.

Frequency Modulation: Three frequency deviation ranges, 0-24 kc., 0-80 kc. and 0-240 kc. are provided, each continuously adjustable. The 0-24 kc. deviation scale is calibrated in increments of 1 kc., the 0-80 kc. scale in increments of 5 kc. and the 0-240 kc. scale in increments of 10 kc.

FM Distortion: The overall FM distortion at 75 kc. is less than 2% and at 240 kc. less than 10%.

Fidelity Characteristics: The deviation sensitivity of the FM modulation system as a function of frequency is flat within ±1 db from 30 cps to 200 kc.

Amplitude Modulation:

1. Internal Modulation: Utilizing the internal audio oscillator, amplitude modulation may be obtained over the range of 0-50%, with meter calibration points provided at 30% and 50% modulation points.
2. External Modulation: By using an external audio oscillator, the RF carrier may be amplitude modulated to substantially 100%. For this purpose the modulation meter has a scale calibration point at 100%.
3. Pulse Modulation: A front panel jack is provided which permits direct connection of an external modulation voltage source to the screen of the final stage for pulse and square wave modulation. When this connection is made, the modulation meter and internal circuits are disconnected from the screen element.

AM Distortion: The distortion present at the RF output for 30% amplitude modulation is less than 3% and for 50% AM less than 6.5%. At 100% AM the distortion is 12% to 15% depending upon the modulating frequency.

The amplitude modulation system, with the modulation potentiometer at maximum position, is flat within ±1 db from 30 cps to 200 kc. With the modulation potentiometer at one-half of full rotation setting, the amplitude modulation system is flat within ±1 db from 30 cps to 70 kc.

Direct connection to the screen element of the final output stage permits square wave or pulse modulation to be applied from an external voltage source. Under these conditions the rise time of the modulated carrier envelope is less than 0.25 microseconds, and the decay time is less than 0.8 microseconds.

Spurious RF Output: All spurious RF output voltages are at least 25 db below the desired fundamental. Total RMS spurious FM from the 60 cycle power source is down more than 50 db, with 75 kc. deviation as a reference level.

Internal AF Oscillator: The internal AF Oscillator may be switched to provide either frequency or amplitude modulation; it may also be switched off. External binding posts permit the use of an external AF oscillator for either AM or FM. The internal oscillator and an external AF oscillator may be used simultaneously, thus producing either FM or AM at two modulation frequencies simultaneously. With the internal oscillator switched for AM, an external AF oscillator may be used simultaneously to frequency modulate the AM signal. The internal AF oscillator provides eight fixed frequencies which may be selected by a rotary type switch —50, 100, 400 cycles and 1, 5, 7.5, 10, 15 kilocycles, accurate to within 5%. Harmonic distortion, in general, is less than 0.5%.

The output voltage of the internal oscillator is available at the external binding posts for synchronizing or other purposes.

External Modulation Requirements:

1. Frequency Modulation: The deviation sensitivity is 50 kc. per volt. For external FM the input impedance is approximately 1500 ohms.
2. Amplitude Modulation: Approximately 45 volts are required for 50% modulation and 100 volts for 100% modulation. For external AM the input impedance is approximately 7500 ohms.
3. Audio Voltage for External Use: There is available at the FM external oscillator binding posts about 5 volts a.c.; at the AM external oscillator binding posts, about 50 volts.

Vernier Frequency Dial: The vernier frequency dial is divided into 100 equal scale divisions and is coupled to the main frequency dial by a 24:1 gear train, providing a total of approximately 2200 logging divisions over the tuning range of the instrument. The approximate frequency change per vernier division is 35 kc.

Accessories:

Furnished:

501-B Output Cable

Available:

207-B Univerter (for covering 0.1 mc. to 55 mcs. frequency range)
Miscellaneous pads and cables

Tube Complement:

1—6AU6	1—5Y3GT/G
1—6V6GT/G	1—6H-6
1—544-A (Selected 6C4)	1—545-A (Selected 3S6/5)
1—543-B (Selected 6AK5)	1—OD3/VR-150
2—543-A (Selected 6AK5)	

Power Requirements: The 202-D FM Signal Generator is designed for use with 115 volts, 50-60 cycles. It will operate satisfactorily, however, over a voltage range from 105-125 volts without changing the RF frequency by more than 0.05%. Power consumption is 65 watts.

Size: Height 17", width 13½", depth 11½".

Weight: 35 lbs. net.
90 lbs. gross packed for export.
47 lbs. gross packed for domestic.
44 lbs. legal weight packed for export.

SIGNAL GENERATOR TYPE 202-E FM-AM

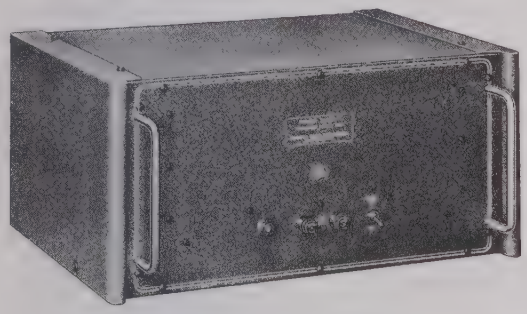
Description

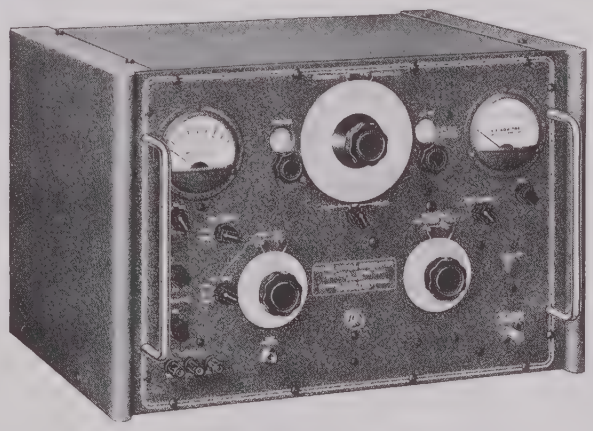
The Type 202-E FM-AM Signal Generator has been developed to meet the needs of engineers engaged in the design of FM and television receivers for operation within the frequency range of from 54 megacycles to 216 megacycles.

This instrument consists of the Signal Generator in one cabinet and the power supply in a second cabinet. End bells are easily detached from the ends of each cabinet to permit mounting in a standard rack. The separate power supply unit permits reduction of the noise level of the carrier and residual FM to an absolute minimum.

An electronic fine tuning control is provided which permits continuous adjustment of the carrier frequency either side of center ± 10 kc in the 54-108 mc. range and ± 20 kc in the 108-216 mc. range. An incremental frequency switch enables the operator to change the carrier frequency by accurately determined increments permitting rapid selectivity measurements. A 60 kc. modulation frequency is included for calibration of the accuracy of the incremental frequency control.

An internal audio frequency oscillator provides eight modulation frequencies ranging from 50 cycles to





Frequency Range 54-216 MC

15 kilocycles, any one of which may be conveniently selected by a rotary type switch for either amplitude or frequency modulation. From an external source modulation may be obtained over the frequency range of 30 to 200,000 cps. Pulse and square wave AM modulation can be obtained by use of external source.

An external audio oscillator may be used in place of the internal modulating oscillator or used in conjunction with the internal oscillator to provide AM and FM simultaneously.

Three deviation ranges: 0-24 kc., 0-80 kc., and 0-240 kc. are available for frequency modulation, and amplitude modulation settings may be made at 30% and 50%.

A calibrated piston type of RF attenuator is used, the range of which is 0.1 microvolts to 0.2 volts. Direct settings in microvolts are made by means of the front panel attenuator dial after the output level has been standardized by adjusting the pointer of the output meter to a single calibration line on the meter scale.

The output cable connects at the front panel by means of a BNC type connector, permitting quick detachment and interchangeability with other output cables.

The unit is finished in grey wrinkle enamel with engraved panel and is supplied complete with tubes and standard output cable.

Specifications

Radio Frequency Characteristics

RF RANGE:
Total Range: 54 to 216 Mc.
No. Bands: 2
Band Ranges: 54 — 108 Mc. 108 — 216 Mc.

RF ACCURACY: ±0.5% (after one hour warmup).

RF CALIBRATION:
Main Dial: Increments of 0.5 Mc. (54 — 108 Mc.). Increments of 1 Mc. (108 — 216 Mc.).
Mechanical Vernier: 2300 divisions through each range.
Electronic Incremental Vernier:

54 — 108 Mc.		108 — 216 Mc.	
±2½ Kc.	±12½ Kc.	± 5 Kc.	±25 Kc.
± 5 Kc.	± 15 Kc.	±10 Kc.	±30 Kc.
±7½ Kc.	± 25 Kc.	±15 Kc.	±50 Kc.
± 10 Kc.	± 30 Kc.	±20 Kc.	±60 Kc.

Electronic Continuous Vernier:
±10 Kc. approx. (54 — 108 Mc.)
±20 Kc. approx. (108 — 216 Mc.)

RF STABILITY: <0.01% per hour (after 2 hour warmup).

RF OUTPUT:
Range: 0.1 μv to 0.2 volts.*
*Across external 50 ohm load.
Accuracy: ±10% approximately.
Impedance: 50 ohms.*
*25 ohms at terminals of Type 501-B Output Cable.
Spurious Output: All spurious RF output voltages are at least 30 db below desired fundamental.

RF LEAKAGE: Sufficiently low to permit measurements at 0.1 μv.

Amplitude Modulation Characteristics

AM RANGE: Internal: 0 — 50%
External: 0 — 50%

AM CALIBRATION: 30, 50%

AM DISTORTION: <5% at 30%
<8% at 50%

AM FIDELITY: ±1 db 30 cps. to 200 Kc.*
*With modulation poteniometer at maximum position.

Frequency Modulation Characteristics

FM RANGE: Internal: 0 — 240 Kc. in three ranges
External: 0 — 240 Kc. in three ranges

FM CALIBRATION: 0 — 24 Kc. in increments of 1 Kc.
0 — 80 Kc. in increments of 5 Kc.
0 — 240 Kc. in increments of 10 Kc.

FM DISTORTION: <2% at 75 Kc.
<10% at 240 Kc.

FM FIDELITY: ±1 db 30 cps. to 200 Kc.

SIGNAL TO NOISE RATIO:
>60 db below 10 Kc. (quiet location)
>55 db below 10 Kc. (average location)

Pulse Modulation Characteristics

PM SOURCE: External

PM RISE TIME: <0.25 μsec.

PM DECAY TIME: <0.8 μsec.

Modulating Oscillator Characteristics

OSC FREQUENCY:	
50 cps.	5 Kc.
100 cps.	7.5 Kc.
400 cps.	10 Kc.
1000 cps.	60 Kc.

OSC ACCURACY: ±5% except 60 Kc. ±2%.

OSC EXTERNAL OUTPUT:
5 volts approximately at external FM posts.
50 volts approximately at external AM posts.

Accessories

FURNISHED: Type 202-EP Power Supply
Type 501-B Output Cable

AVAILABLE: Type 502-B Patching Cable (Page 34).
Type 504-A Adapter (Page 34).
Type 505-B Attenuator (Page 34).
Type 506-B Patching Cable (Page 34).
Type 507-B Adapter (Page 34).
Type 508-B Adapter (Page 35).
Type 509-B Attenuator (Page 35).
Type 510-B Attenuator (Page 35).
Type 514-B Output Cable (Page 35).
Type 517-B Output Cable (Page 35).

Tube Complement

1 — OD3	1 — 545-A
1 — 5Y3GT	1 — 6AU6
2 — 543-A	1 — 6H-6 Ballast
1 — 543-B	1 — 6V6-GT
1 — 544-A	

Physical Characteristics

MOUNTING: Two separate cabinets for bench use; by removal of end bells, suitable for 19" rack mounting.

FINISH: Gray wrinkle, engraved panel (other finishes available on special order).

DIMENSIONS:	202-E	202-EP
Height:	12 7/32"	8 23/32"
Width:	19"	19"
Depth:	12¾"	12¾"

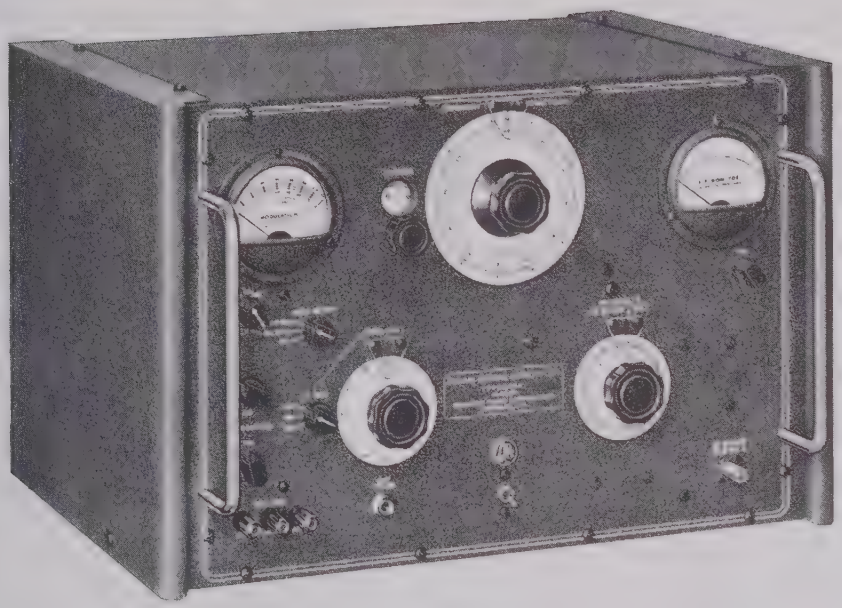
INTERCONNECTING CABLE: Five wire 42" long cable, permanently attached to 202-EP.

WEIGHT:
Net: 58 lbs. Gross Export: 122 lbs.
Gross Domestic: 72 lbs. Legal Export: 65 lbs.

Power Requirements

202-E: 105 — 125 volts, 50-60 cps., 65 watts

SIGNAL GENERATOR TYPE 202-F: FM-AM



Frequency Range 175-250 MC

DESCRIPTION

The Type 202-F Signal Generator is a precise and reliable instrument well suited to the specialized requirements of telemetering engineers for rapidly analyzing overall system performance. It is very similar in design and appearance to the 202-E FM-AM Signal Generator but it has a frequency coverage of from 175-250 mc., provided in a single range. The 202-F is mounted in a single cabinet equipped with easily removable endbells. When the endbells are removed the instrument may be mounted in a standard rack.

An internal audio frequency oscillator furnishes eight modulation frequencies ranging from 50 cycles to 15 kilocycles, any one of which may be selected by a rotary type switch for either amplitude or frequency modulation.

Three deviation ranges: 0-24 kc., 0-80 kc., and 0-240 kc. are available for frequency modulation, and amplitude modulation, settings may be made at 30% and 50%. By means of an external audio oscillator, amplitude modulation to substantially 100% may also be obtained, and a front panel jack permits the connection of an external modulation source for pulse and square wave modulation.

The Type 202-F Signal Generator is finished in grey wrinkle enamel with engraved panel and is supplied complete with tubes and standard Type 501-B output cable.

SPECIFICATIONS

RF Range: Overall frequency coverage 175-250 megacycles in one range, accurate to ±0.5% after a warm-up period of one hour. The main frequency dial is also calibrated in 24 equal divisions for use with the vernier frequency dial.

RF Output Voltage: The maximum open circuit output voltage from the BNC type RF output jack at the front panel is about 0.4 volt. With the standard output cable (type 501-B) attached, the maximum calibrated output voltage at the cable terminals is 0.2 volt nominal. When the RF monitor meter is set to the red calibration line and the standard output cable attached, the RF output attenuator is direct reading in microvolts and continuously adjustable from 0.1 microvolt to 0.2 volt.

RF Output Impedances: The RF output impedance of the signal generator as seen looking in at the BNC type front panel connector is 50 ohms. With the standard output cable attached, the RF output impedance as seen looking in at the output cable terminals is 25 ohms.

Frequency Modulation: Three frequency deviation ranges, 0-24 kc., 0-80 kc. and 0-240 kc. are provided, each continuously adjustable. The 0-24 kc. deviation scale is calibrated in increments of 1 kc., the 0-80 kc. scale in increments of 5 kc. and the 0-240 kc. scale in increments of 10 kc.

FM Distortion: The overall FM distortion at 75 kc. is less than 2% and at 240 kc. less than 10%.

Fidelity Characteristics: The deviation sensitivity of the FM modulation system as a function of frequency is flat within ±1 db from 30 cps to 200 kc.

Amplitude Modulation:

1. Internal Modulation: Utilizing the internal audio oscillator, amplitude modulation may be obtained over the range of 0-50%, with meter calibration points provided at 30% and 50% modulation points.

2. External Modulation: By using an external audio oscillator, the RF carrier may be amplitude modulated to substantially 100%. For this purpose the modulation meter has a scale calibration point at 100%.

3. Pulse Modulation: A front panel jack is provided which permits direct connection of an external modulation voltage source to the screen of the final stage for pulse and square wave modulation. When this connection is made, the modulation meter and internal circuits are disconnected from the screen element.

AM Distortion: The distortion present at the RF output for 30% amplitude modulation is less than 3% and for 50% AM less than 6.5%. At 100% AM the distortion is 12% to 15% depending upon the modulating frequency.

The amplitude modulation system, with the modulation potentiometer at maximum position, is flat within ±1 db from 30 cps to 200 kc. With the modulation potentiometer at one-half of full rotation setting, the amplitude modulation system is flat within ±1 db from 30 cps to 70 kc.

Direct connection to the screen element of the final output stage permits square wave or pulse modulation to be applied from an external voltage source. Under these conditions the rise time of the modulated carrier envelope is less than 0.25 microseconds, and the decay time is less than 0.8 microseconds.

Spurious RF Output: All spurious RF output voltages are at least 25 db below the desired fundamental. Total RMS spurious FM from the 60 cycle power source is down more than 50 db, with 75 kc. deviation as a reference level.

Internal AF Oscillator: The internal AF Oscillator may be switched to provide either frequency or amplitude modulation; it may also be switched off. External binding posts permit the use of an external AF oscillator for either AM or FM. The internal oscillator and an external AF oscillator may be used simultaneously, thus producing either FM or AM at two modulation frequencies simultaneously. With the internal oscillator switched for AM, an external AF oscillator may be used simultaneously to frequency modulate the AM signal. The internal AF oscillator provides eight fixed frequencies which may be selected by a rotary type switch —50, 100, 400 cycles and 1, 5, 7.5, 10, 15 kilocycles, accurate to within 5%. Harmonic distortion, in general, is less than 0.5%.

The output voltage of the internal oscillator is available at the external binding posts for synchronizing or other purposes.

External Modulation Requirements:

1. Frequency Modulation: The deviation sensitivity is 50 kc. per volt. For external FM the input impedance is approximately 1500 ohms.

2. Amplitude Modulation: Approximately 45 volts are required for 50% modulation and 100 volts for 100% modulation. For external AM the input impedance is approximately 7500 ohms.

3. Audio Voltage for External Use: There is available at the FM external oscillator binding posts about 5 volts a.c.; at the AM external oscillator binding posts, about 50 volts.

Vernier Frequency Dial: The vernier frequency dial is divided into 100 equal scale divisions and is coupled to the main frequency dial by a 24:1 gear train, providing a total of approximately 2200 logging divisions over the tuning range of the instrument. The approximate frequency change per vernier division is 35 kc.

Accessories:

Furnished:

501-B Output Cable

Available:

207-F Univerter (for covering 0.1 mc. to 55 mcs. frequency range)
Miscellaneous pads and cables

Tube Complement:

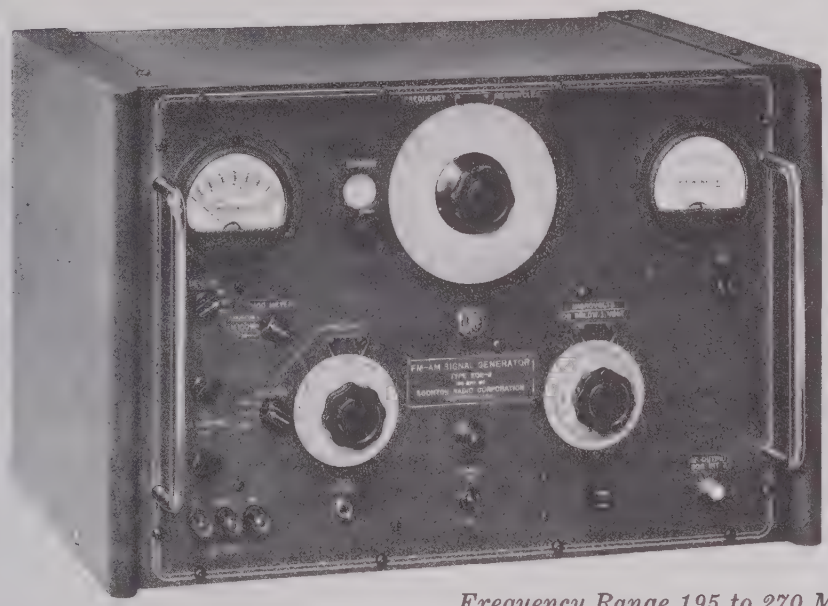
1—6AU6	1—5Y3GT/G
1—6V6GT/G	1—6H-6
1—544-A (Selected 6C4)	1—545-A (Selected 3S6/5)
1—543-B (Selected 6AK5)	1—OD3/VR-150
2—543-A (Selected 6AK5)	

Power Requirements: The 202-F FM-AM Signal Generator is designed for use with 115 volts, 50-60 cycles. It will operate satisfactorily, however, over a voltage range from 105-125 volts without changing the RF frequency by more than 0.05%. Power consumption is 65 watts.

Size: Rack Mounting: Height 12 7/32", width 19", depth 12 3/4".
Cabinet Mounting: Height 13", width 19 1/8", depth 12 3/4".

Weight: 35 lbs. net.
90 lbs. gross packed for export.
47 lbs. gross packed for domestic.
44 lbs. legal weight packed for export.

SIGNAL GENERATOR TYPE 202-G: FM-AM



Frequency Range 195 to 270 Mc.

Description

The Signal Generator Type 202-G is a precise and reliable instrument well suited to the specialized requirements of telemetering engineers for rapidly analyzing over-all system performance. It is very similar in design and appearance to the 202-E FM-AM Signal Generator but offers RF coverage from 195 to 270 Mc. completely blanketing the 215 to 260 Mc. telemetering band.

The instrument incorporates an oscillator and two doubler circuits which are mounted on a rugged aluminum casting and completely shielded to provide extremely low leakage. A precision backlash-free gear train is incorporated for adjusting output frequency. A waveguide-below-cutoff piston attenuator provides a continuous adjustment of RF output level which is monitored on a "set to line" meter.

Both AM and FM modulation is available, indicated on a panel meter, from either the internal audio oscillator or an external source. Pulse modulation may also be obtained from an external source. The cabinet is designed for bench use; by simple removal of the cabinet end bells, the instrument may be mounted into a standard 19" rack. The unit is finished in gray wrinkle enamel.

Features

The 202-G is carefully designed to simplify the testing and calibration of FM telemetering systems in that a choice of eight standard RDB audio modulating frequencies are available for internal modulation.

Simultaneous FM and AM modulation may be obtained for checking the performance of telemetering receivers in the presence of amplitude modulation.

Through the use of a precision backlash-free gear train, approximately 2200 vernier logging divisions are provided over the RF range permitting accurate frequency adjustment against crystal controlled receivers.

Specifications

Radio Frequency Characteristics

RF RANGE: 195 — 270 Mc.

RF ACCURACY: ±0.5% (after one hour warmup).

RF CALIBRATION:
Main Dial: Increments of 0.5 Mc.
Vernier: 2200 divisions through range.

RF OUTPUT: Range: 0.1 μv to 0.2 volts.*
*Across external 50 Ω load.
Accuracy: ±10% approximately.
Impedance: 50 Ω*
*25 Ω at terminals of Type 501-B Output Cable.
Spurious Output: All spurious RF output voltages are at least 25 db below the desired fundamental.

RF LEAKAGE: Sufficiently low to permit measurements at 0.1 μv.

Amplitude Modulation Characteristics

AM RANGES: Internal: 0 — 50%
External: 0 — 100%

AM CALIBRATION: 30, 50, 100%

AM DISTORTION: < 5% at 30%
< 8% at 50%
<20% at 100%

AM FIDELITY: ±1 db 30 cps. to 200 Kc.*
*With modulation potentiometer at maximum position.

EXTERNAL AM REQUIREMENTS:
Approximately 100 volts RMS into 7500 Ω for 100% AM.

Frequency Modulation Characteristics

FM RANGE: Internal: 0 — 240 Kc. in three ranges
External: 0 — 240 Kc. in three ranges

FM CALIBRATION: 0 — 24 Kc. in increments of 1 Kc.
0 — 80 Kc. in increments of 5 Kc.
0 — 240 Kc. in increments of 10 Kc.

FM DISTORTION: < 2% at 75 Kc.
<10% at 240 Kc.

FM FIDELITY: ±1 db 30 cps. to 200 Kc.

EXTERNAL FM REQUIREMENTS:
Approximately 5 volts RMS into 1500 Ω for 240 Kc. deviation.

SPURIOUS FM: Total RMS spurious FM from 60 cps. power source is at least 50 db below 75 Kc.

Pulse Modulation Characteristics

PM SOURCE: External.

PM RISE TIME: <0.25 μsec.

PM DECAY TIME: <0.8 μsec.

Modulating Oscillator Characteristics

OSC FREQUENCY:	50 cps.	3.9 Kc.
	400 cps.	10.5 Kc.
	730 cps.	30 Kc.
	1700 cps.	70 Kc.

OSC ACCURACY: ±5%

OSC EXTERNAL OUTPUT:
5 volts approximately at external FM posts.
50 volts approximately at external AM posts.

Accessories

FURNISHED: Type 501-B Output Cable.

AVAILABLE: Type 502-B Patching Cable
Type 504-A Adapter
Type 505-B Attenuator
Type 506-B Patching Cable
Type 507-B Adapter
Type 508-B Adapter
Type 509-B Attenuator
Type 510-B Attenuator
Type 514-B Output Cable
Type 517-B Output Cable

Tube Complement

1 — OD3	1 — 543-B	1 — 6AU6
1 — 5Y3GT	1 — 544-A	1 — 6H-6 Ballast
2 — 543-A	1 — 545-A	1 — 6V6-GT

Physical Characteristics

MOUNTING: Cabinet for bench use; by removal of end bells, suitable for 19" rack mounting.

FINISH: Gray wrinkle, engraved panel (other finishes available on special order).

DIMENSIONS: Height: 12 7/32" Width: 19" Depth: 12¾"

WEIGHT:
Net: 35 lbs. Gross Export: 90 lbs.
Gross Domestic: 47 lbs. Legal Export: 44 lbs.

Power Requirements

202-G: 105-125 volts, 50-60 cps., 65 watts

SECTIONS II THRU IX

TEST AND ALIGNMENT PROCEDURES

The following sections are presented in the sequence recommended for complete test and alignment of the Signal Generator.

Voltages and other Test and Alignment data given in these procedures should not be considered as "specifications" of the instruments, but rather as "typical limits" which will assure operation of the instrument within the guaranteed "Catalog Specifications" given in Section I.

The procedures as outlined are applicable to all 202 Series Signal Generators (202B thru 202G). Differences between Generators have been indicated in the text as appropriate.

11 POWER SUPPLY

A. DC Filament Supply Test & Adjustment (202C/E)

1. Set AC line voltage to 117 VAC.

2. Set INT MOD switch to OFF; AM and FM Modulation Controls to minimum.

3. Adjust R92 for 6.5 volts DC on low-voltage side of R91 (pin 5 of ballast tube socket); AC ripple should be less than 55 mv, RMS.

4. Measure regulated DC voltage at pin 2 of ballast tube socket; it should be between 6.6 and 7.0 volts.

5. From low to high line (105V-125V) the regulated filament voltage variation should be within 0.2V; at the low line it must be at least 6.6V, and at high line not over 7.0 volts.

SERVICE NOTE: If required to cause the voltage to remain between 6.6V and 7.0V the resister shunting the ballast tube may be reconnected between the output of the ballast tube and ground; change value as required to keep voltage within limits. Should variations be greater than 0.2V replace ballast tube. If resistor is not present it may be added -- in no case should regulated filament voltage at output of 6H-6 rise above 7.0 volts.

B. AC Filament Supply Test (202B/D/F/G)

1. Measure unregulated heater supply (pins 4 and 8 of P2 in 202D/F/G; pin 4 to ground in 202B). At 117 VAC line, it should be 6.0 - 6.6 volts.

2. Voltage to input of 6H-6 should be approximately 13.5 VAC, with 117 VAC line voltage.

3. Measure regulated heater supply (pin 5 of P2, to ground).

4. Test as in paragraph A-5 above.

C. B+ Test and Adjustment

1. Measure "High DC" at junction of L4 and R19. At 117 volt line, it should be nominally:

250-280 Volts DC (202B/C/D/E/F)
225-255 Volts DC (202G)

AC ripple should be less than 20. mv, RMS.

2. Measure "Regulated DC" at pin 5 of VR tube; it should remain within 147V to 155V from high to low line (105-125 VAC). Maximum change is 3 volts. Adjust R19 as required.

NOTE: R19 may also be adjusted by measuring VR tube current. Set R19 such that current is 7 ma at 105V line, and about 40 ma at 125V line.

3. AC ripple should be less than:

12 mv (202B/D/F/G)
1 mv (202C/E)

III AUDIO UNIT

A. Output Level Adjustment

1. Set INT. MOD. switch to AM, FREQ. cps dial to 400 cps, and AM and FM Modulation Controls to minimum.

2. Adjust R12 for 55 volts (400 cps) at the AM - EXT. OSC. terminals.

3. Change the FREQ. cps dial to each of the other frequencies; any variations within the range of 50 to 60 volts are acceptable. Readjust R12 if required. NOTE: 60 KC on 202C/E's may be less than 50 V.

4. Set INT. MOD. switch to FM, and return the FREQ. cps dial to 400 cps. The 400 cps voltage at FM -EXT. OSC. terminals should measure 10-13 volts.

B. Audio Distortion Test

1. Using a Distortion Analyzer (-HP-330B, or equivalent), measure the Total Harmonic Distortion of the audio voltage appearing at the FM - EXT. OSC. terminals (INT. MOD. switch must be in FM position). Distortion should be less than 0.5%.

C. Audio Frequency Test

1. Using an electronic counter, or other appropriate method for measuring audio frequencies, each frequency should be within ±5%. Measure at FM - EXT. OSC. terminals; INT. MOD. switch in FM position.

2. "60 KC" on 202C and 202E can be adjusted to within ±2% using C51; "70 KC" on 202G can be adjusted to within ±5% using C6.

IV FM VOLTAGE DIVIDER NETWORK

A. Test of Switching and Resistor Accuracy

1. Set INT. MOD. switch to FM; FREQ. cps dial to 400 cps.

2. Adjust front-panel FM deviation control for exactly 3.6 volts (400 cps) on its center (wiper) terminal.

3. Measure the 400 cps voltage at the junction of R41 and R45 in RF Unit (remove shield can). The voltage should measure within limits as follows:

DEV-KC Switch Position	Single Band, 202D/F/G 54-108MC Band, 202B/C/E	202B/C/E 108 2.6MC Band
240 KC	1.78 - 1.82 V	.890 - .910 V
80 KC	.588 - 612 V	.294 - .306 V
24 KC	.176 - .184 V	.088 - .092 V

Should voltages be out of tolerance, locate and replace defective resistor(s) in the voltage divider network.

V FM DEVIATION METER CIRCUITRY

A. FM Meter Calibration

1. Set INT. MOD. switch to FM; FREQ. cps dial to 400 cps. If a 202B/C/E, set band switch to 54-108 MC.

2. Set DEV-KC switch to 80 KC range, and set FM deviation control for exactly 0.7 volts (400 cps) at the junction of R41 and R45.

3. Adjust R29 for a reading of exactly 70 KC on the MODULATION meter.

B. FM Tracking Test

1. Successively adjust FM deviation control to each major calibration mark (80, 70, 60, 50 etc.); the voltage at junction R41 and R45 should correspond to deviation reading within ± .02 volt. (Example: .8 ± .02 V for 80 KC; .1 ± .02 V for 10 KC; etc.).

C. FM Fidelity Test (modulation system frequency response)

1. Turn AC power OFF; set INT. MOD. switch to OFF, FM control maximum clockwise, DEV-KC switch to 240 KC (if 202B/C/E, use 54-108 MC band).

2. Apply audio voltage from an external oscillator (-HP-650A or equivalent) to the FM - EXT. OSC. terminals.

3. Measure the audio voltage at the junction of R44 and R45. (Use an audio voltmeter having less than 5 pf input capacitance on 202D/E/F/G's).

4. With 400 cps applied from test oscillator, adjust FM control for 240 KC (full scale) on the MODULATION meter.

5. Vary the frequency of the externally applied audio voltage to the extremes of the specified range, (see FM FIDELITY specification for instrument in Section 1 of this manual). For each frequency, change the externally applied voltage to obtain "240 KC" on the MODULATION meter. Read the change in voltage at the junction of R44 and R45; the total change in voltage over the specified frequency range should remain within the specified db limits.*

6. Repeat test with DEV-KC switch in 80 KC position.

D. External FM Requirements

1. Connect an external audio oscillator to the FM - EXT. OSC. terminals; monitor voltage with AC VTVM.

2. Set frequency to 400 cps; FM control full clockwise.

3. Increase applied voltage for MODULATION meter reading of 240 KC. Approximately 4.8 to 5 volts should be required.

VI RF UNIT TEST AND ALIGNMENT

Tracking and realignment of the oscillator, doubler, and/or amplifier-doubler in the RF Unit may be required to obtain the following:

1. Sufficient RF output at specific points on the band.

2. To equalize RF outputs on high and low frequency bands, (202B/C/E/only), such that both have sufficient output.

3. Minimized incidental AM with FM (NOTE: There is no catalog specifications on this, however, 10% AM or less is "Typical" with 240 KC deviation).

4. Proper alignment whenever any components (even a tube) is replaced in RF Unit.

* FM Fidelity Specification for 202D's below serial number 2600 is same as that for 202C's.

NOTES: (IMPORTANT)

1. If necessary to adjust trimmer screws in RF Unit, loosen with poly-thinner (or other appropriate solvent) before attempting to turn; hot soldering iron may be applied to lossen glyptal. Use screw-driver and, with light pressure, loosen in a <u>counterclockwise</u> direction. <u>CAUTION</u>: Unless trimmers are "free" it is possible to inadvertently screw them in too far, and crack ceramic stator mounts.

2. Shielded leads should be used for <u>ALL</u> external connections during test and/or alignment procedures.

3. On 202C/E, ΔF control must be set to "0" and <u>fine tuning control</u> to center of range for proper alignment.

4. On 202B/C/E, low frequency range (54-108 MCs) should be used for test and/or alignment.

5. Before checking alignment, see that all tubes are selected BRC 543A, "Red-Tip" (V8), 543B (V7), 544A (V6), and 543A or 543C "Blue-Tip" (V5). These BRC pre-tested and selected tubes are recommended for the most expedient realignment to specifications.

6. Tube replacement will necessitate dial slipping and/or trimmer adjustment, ONLY; no plate bending should be required.

A. <u>Testing the RF Unit</u>

Before actual adjustments within the RF Unit, the following tests should be made to determine the nature and extent of any trouble that may exist. (For information on Reactance Modulator Circuitry, see page 29

1. <u>Check CW Frequency Calibration</u>

Use a crystal calibrator or electronic counter (spec: ±0.5% after one hour warm-up). Page 26 gives procedure for adjustment, if required.

2. <u>Check for Sufficient RF Output</u>

Weak RF Output (inability to reach "Red-Line") may be caused by weak tubes, or by detuning or mis-tracking of the tuned stages at specific frequencies across the band(s). Weak tubes or First Doubler detuning are evidenced by the inability to reach "Red-Line" generally across the entire frequency band. The need for re-tracking of the tuned stages is evidenced when the RF MONITOR meter will not reach "Red-Line" at some frequencies, while having more than ample reserve at others.

NOTE: Monitor actual RF output jack to assure that "Red-Line" reading on panel meter is a true indication of the attenuator calibration.

To check, proceed as follows:

(A) 202B/C/E

(1) Turn RF control full clockwise.

(2) Rotate FREQUENCY dial across the band while observing RF MONITOR meter; the indicator should remain above "Red-Line" at all frequencies on BOTH frequency bands.

NOTE: for sufficient RF Output "reserve", the indicator should remain at least half-way between "Red-Line" and full scale.

(B) 202D/F/G

(1) Measure DC voltage on screen grid of V8 (NOTE: this is conveniently measured thru the "tip" of a phone plug inserted into EXT PLUSE jack. Do not break contact within J1; only insert the plug far enough to just touch and indicate the DC voltage on a 0-100 volt DC meter.

(2) Advance RF control for a reading of 78 V DC.

(3) Rotate FREQUENCY dial across the band while observing RF MONITOR meter; the indicator should remain above "Red-Line" at all frequencies across the band.

3. Check Tracking of Doubler Stage

(A) Connect equipment as follows: (instrument out of cabinet; RF can be removed)

(1) Disconnect R56 (100 KΩ, 1/2 W resistor) at ground lug mounted on tube-shelf, near casting. (The other end of R56 remains connected to C43 and grid of V8).

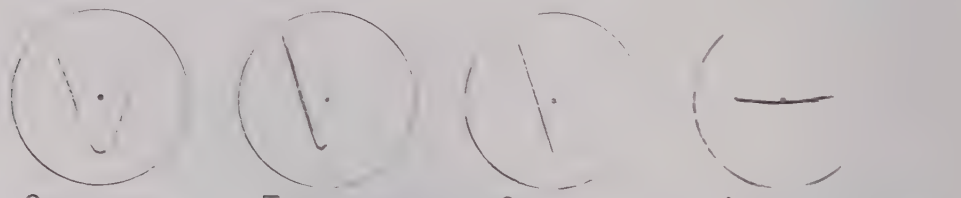
(2) Connect Vertical oscilloscope input to free end of R56.

(3) Connect Horizontal oscilloscope input (external sweep) to FM and GND terminals of generator.

(4) Set INT. MOD. switch to FM, and FREQ cps to 400 cps.

(5) Set MOD. Meter switch to FM, DEV-KC switch to 240 KC, and adjust FM MOD control for 150 KC on MODULATION meter.

(B) THE OSCILLOSCOPE WAVEFORM SHOULD BE "U-SHAPED". ROTATE MAIN TUNING DIAL ACROSS BAND -- AS LONG AS A "HOOK" IS ON THE TRACE, THE DOUBLER IS IN TRACK. THIS SCOPE PATTERN IS THE RESONANCE CURVE OF THE TANK CIRCUIT; FOR PERFECT TRACKING, THE TRACE SHOULD BE A SYMETRICAL "U".



OPTIMUM TRACKING (SYMETRICAL WAVEFORM)

TRACKING OK (STILL HAS "HOOK")

OUT OF TRACK (NO "HOOK" ON WAVEFORM)

INSUFFICIENT SCOPE VERT. GAIN OR OUTPUT FROM STAGE

(C) HINT: TO DETERMINE IF BENDING CAPACITOR PLATE SERRATIONS WILL IMPROVE TRACKING AT A PARTICULAR FREQUENCY DIAL SETTING; PLACE FINGER NEAR (BUT DO NOT TOUCH) STATOR OF AMPLIFIER STAGE BEING TESTED.

(1) IF SCOPE PATTERN BECOMES MORE SYMETRICAL, BENDING SERRATED PLATE OF AMPLIFIER STAGE IN (TO INCREASE CAPACITY) WILL IMPROVE TRACKING.

(2) IF SCOPE PATTERN BECOMES LESS SYMETRICAL, PLACE FINGER NEAR (BUT DO NOT TOUCH) STATOR OF OSCILLATOR STAGE -- PATTERN SHOULD BECOME MORE SYMETRICAL. IN THIS CASE BENDING AMPLIFIER STAGE PLATE SERRATION OUT WILL IMPROVE TRACKING.

(D) IF IN TRACK, RECONNECT R56; IF NOT SEE PAGE 26 FOR ADJUSTMENT PROCEDURE.

4. CHECK TRACKING OF AMPLIFIER-DOUBLER STAGE

(A) USE SAME EQUIPMENT SET-UP AS IN CHECKING DOUBLER STAGE WITH THE FOLLOWING EXCEPTIONS:

(1) UNSOLDER "HOT" WIRE (USUALLY YELLOW WITH RED TRACER) FROM RF MONITOR METER (M1). (R56 SHOULD BE RECONNECTED AFTER CHECKING DOUBLER TRACKING).

(2) CONNECT VERTICAL OSCILLOSCOPE INPUT TO FREE END OF UNSOLDERED WIRE.

(B) The oscilloscope waveform should be an "inverted-U", similar to that shown in the figure above (but inverted). Rotate main tuning dial across band (NOTE: use low frequency band on 202B/C/E). As long as a "hook" is on the trace at ±150 KC deviation, the Amplifier-Doubler is in track. See HINT (C) on previous page.

(C) If in track, resolder wire to M1; if not, see page 27 for adjustment procedure.

B. Tracking and Realignment of Oscillator, Doubler and Amplifier-Doubler Stages

1. Mechanical Pre-Alignment (power removed from instrument)

(A) With generator removed from cabinet, and can off of RF Unit, set main AND vernier frequency dials to "0" (on Red scales).

(B) Check rotor plates of Oscillator, Doubler, and Amplifier-Doubler stages -- they should be fully meshed, with edges just FLUSH with stator plates; if they are not, proceed as in (C) and (D) below.

(C) "Slip" main frequency dial (if necessary) so "0" on both Main and Vernier Frequency Dials coincide; keep rotor and stator plates as nearly "flush" as possible.

(D) Align rotors with stator plates (flush) by loosening the single Allen set-screw on brass gear (on main shaft of gear train; near rear of RF Unit). Use Allen wrench as lever to turn gear (hold dial) and properly mesh plates.

CAUTION: This gear also drives a large split-gear to which the Deviation Plates are attached. Rotate gear only; do not slip along shaft, as loss of gear mesh will loose "split" and proper positioning of Deviation Rotor Plates. Should this happen, top of deviation plates should be fully OUT OF MESH (just starting into mesh) when the other rotors are fully meshed, and flush; load the split gears - about two teeth.

2. Electrical Alignment

(A) Loosen appropriate trimmer screws as previously discussed under "NOTES". (Power disconnected from instrument).

(B) All adjustments are adjacent to tube shields on tube-shelf and are as follows:

202B/C/E - C57, C58, C59; brass threaded slugs--9/32" diameter - on tube shelf. (Not shown on 202B schematic).

202D/F/G - C54, C52, C51; glass trimmer capacitors.

All 202's - Serrated rotor plates on variable tuning capacitors.

(C) Frequency Calibration (If 202B/C/E, calibrate on LOW frequency range, high frequency range is "doubled" so accuracy will be retained). Use crystal calibrator or electronic counter at RF OUTPUT jack. Turn AC power on; allow at least a one hour warm-up period.

(1) Set Main Frequency Dial to highest frequency calibration mark.

(2) Adjust C57 for exact frequency corresponding to dial mark.

(3) Replace shield can; note difference in frequency.

(4) Remove shield can and readjust C57 so frequency is correct when can is replaced. Note frequency shift when can is removed, and track accordingly over rest of band.

(5) Reduce frequency in 1,5, or 10 MC steps, bending each serrated plate as required to "track" output frequency with dial markings. (Consider frequency shift due to RF cans being off).

(6) When RF shield can is installed, output frequency should be within ±0.5% of dial calibration.

(D) Tracking of Doubler Stage

(1) Connect equipment as previously discussed under "check tracking of doubler stage".

(2) If 202B/C/E, use low frequency range.

(3) Start tracking at high frequency end of band.

(4) Adjust Doubler Stage Trimmer capacitor for best U-shaped trace (±150 KC deviation).

(5) Bend serrated variable capacitor plates as frequency is reduced so at least a "hook" appears on the oscilloscope trace at all frequencies.

(6) Reconnect R56 to ground.

(E) Tracking of Amplifier-Doubler Stage

(1) Connect equipment as previously discussed under tracking of Amplifier-Doubler Stage.

(2) If 202B/C/E, use lower frequency range.

(3) Set frequency dial to high frequency end of band.

(4) Adjust Amplifier-Doubler stage trimmer capacitor for best inverted-U trace (±150 KC deviation).

(5) Bend serrated variable capacitor plates so at least a "hook" appears on the oscilloscope trace at ALL frequencies.

(6) Resolder meter lead to meter.

(F) Equalizing Tracking for Optimum RF Output on both high and low bands (202B/C/E, only).

(1) Set frequency dial to 108 MC/216 MC (high end of band).

(2) Switch between ranges, observing RF MONITOR meter, while making adjustments (3) and (4) below.

(3) Make VERY SLIGHT adjustments to Doubler and Amplifier-Doubler trimmer capacitors as necessary to obtain sufficient RF output on BOTH frequency ranges; it may be necessary to optimize tuning between the two bands.

(4) Without further adjustment of trimmer, start at 105 MC/210 MC on dial and check equality of RF MONITOR meter readings as range switch is switched back-and-forth, and frequency is reduced in approximately 10 MC steps.

HINT: To determine which way to bend plate serrations for optimum equalized RF output, proceed as follows:

(1) Place one finger near (but do not touch) stator of oscillator stage -- if RF MONITOR meter needle drops down, put finger near Amplifier-Doubler stator -- if needle goes down again the Amplifier-Doubler is IN TRACK.

(2) If needle goes up when finger is near oscillator stator, the Amplifier-Doubler plates must be bent out (less capacity).

(3) If the needle goes up when finger is near Amplifier-Doubler stator, the Amplifier-Doubler plates must be bent in (more capacity).

(4) Use this "finger method" to check and optimize equality of RF output as frequency is changed, in gradual steps, over the band (start at highest frequencies)

(5) Switch from low to high range, and make adjustments to favor the weaker output; always switch back to be sure the adjustment hasn't removed too much output from the other range.

(6) At weak points across the range, some RF output can be gained by very slightly bending the plates of the Doubler rotor with a thin insulated rod.

NOTE: If RF output cannot be optimized on both frequency bands, while still retaining tracking within ±150 KC, it may be necessary to slightly reposition turns on L19. The inductance ratio should be such that HIGH band and LOW band inductance of L19 will track with the common variable tuning capacitor, C50. Loosen coil-dope with thinner, reposition as appropriate and then re-dope. If wire becomes stretched, or badly deformed, replace entire coil.

(G) If Amplifier-Doubler was adjusted, re-check first Doubler for proper alignment.

C. Reactance Modulator Adjustment and Tracking

1. Methods of measuring FM Deviation and Distortion are discussed in the Appendix; other methods are undoubtedly available. This procedure contains only the techniques for adjustment of the Reactance Modulator Circuit.

2. Although NOT a catalog specification, FM Deviation accuracy can be adjusted to approximately ±5% across the frequency band(s). Make adjustments at 75 KC Deviation.

3. NOTES: The adjustments to be made are of R47, R50 and C33. R47 and R50 both determine the operating points of the Reactance Modulator Circuit, hence interaction is normal. If one is adjusted, the other must be checked for optimum setting.

PROCEDURE:

1. Set FREQUENCY MEGACYCLES dial to lowest frequency (C33 fully OUT of mesh).

2. Set DEV KC switch to 80 KC, and adjust FM MOD CONTROL for a reading of 75 KC on the front-panel MODULATION meter.

3. Adjust R47 for 75 KC deviation as measured externally. (See methods in Appendix A)

4. Adjust R50 for minimum total harmonic distortion (see methods in Appendix B). If minimum distortion is greater than 2% THD, try another reactance tube.

5. Turn FREQUENCY MEGACYCLES dial to high frequency end. Again check distortion as in (4) above.

6. Successively readjust interacting R47 and R50 such that:

   (a) Deviation at LOW END of band is 75 KC.

   (b) Distortion is optimized (but less than 2% THD) between opposite ends of the frequency band.

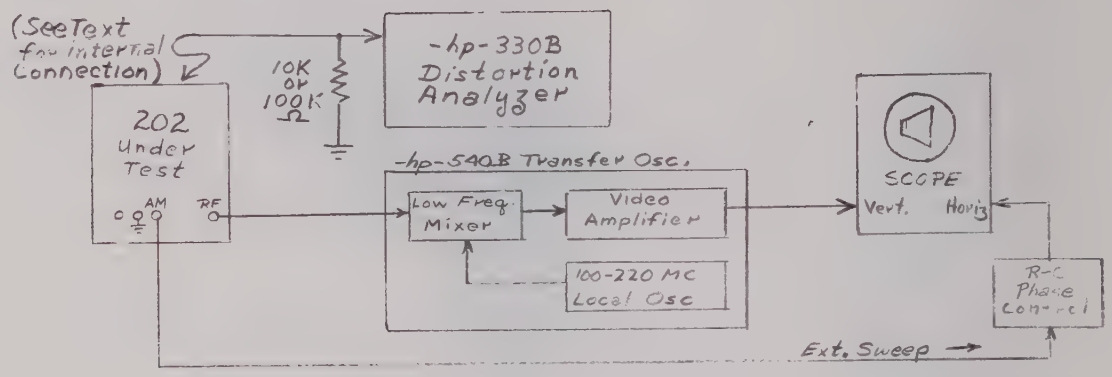
7. Return FREQUENCY MEGACYCLES dial to LOW end of the band (C33 completely OUT of mesh).

8. At 10 MC increments across the band, the deviation rotor plates may be adjusted to give a constant FM deviation, as measured externally. The segmented plates are adjusted by increasing capacitance (bend plates in) to reduce deviation, or by decreasing capacity (bend plates out) to increase deviation.

9. Recheck Deviation and Distortion at 10 MC increments across the band. THD should be less than 2% and deviation nominally 75 KC (note that there is no catalog specification on FM Deviation ACCURACY for the 202B thru 202G).

10. TOTAL HARMONIC DISTORTION AT 240 KC DEVIATION SHOULD MEASURE 10% OR LESS. CAUTION SHOULD BE TAKEN TO SEE THAT THE DISCRIMINATOR USED IS NOT A MAJOR CONTRIBUTOR TO TOTAL THD.

VII AMPLITUDE MODULATION METER CIRCUITRY



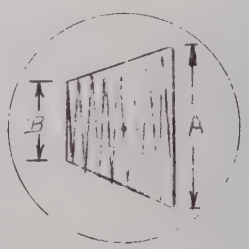
A. PROCEDURE FOR MEASUREMENT OF PERCENT AM & AM DISTORTION

1. CONNECT EQUIPMENT AS SHOWN ABOVE.
2. SET RF MONITOR METER TO "RED-LINE".
3. UNSOLDER UNGROUNDED (USUALLY YELLOW) LEAD FROM RF MONITOR METER ON 202 GENERATOR.
4. CONNECT DISTORTION ANALYZER INPUT BETWEEN UNSOLDERED LEAD AND GROUND; CONNECT 10 K OR 100 KΩ RESISTOR ACROSS DISTORTION ANALYZER INPUT TERMINALS.
5. BEAT 540B INTERNAL OSCILLATOR WITH RF FROM 202 GENERATOR, SUCH THAT I.F. FREQUENCY FROM VIDEO AMPLIFIER IS WITHIN BANDPASS OF SCOPE.
6. PERCENT AM MAY NOW BE MEASURED BY THE "TRAPEZOID METHOD", WHERE:

$$\% \text{ AM} = \frac{A-B}{A+B} \times 100$$

FOR A = 10 CM:

*100% AM, B=0
50% AM, B=3.3 CM
30% AM, B=5.4 CM



NOTE: PERCENT AM ACCURACY IS NOT SPECIFIED ON 202B-202G

* USE AN EXTERNAL AUDIO OSCILLATOR (THD < 0.5%). TO OBTAIN 100% AM ON 202D/F/G, APPROXIMATELY 100 VOLTS INTO 7.5 KΩ IS REQUIRED.

7. AM Distortion may be simultaneously measured using convention Distortion Analyzer techniques. Specifications are given in Technical Data and Specifications, Section 1, of this manual

B. Percent AM Meter Calibration

1. Reconnect yellow wire to RF MONITOR meter and set to "Red-Line" with RF control.

2. (202D/F/G, only) - Set MOD METER switch to "AM 100%"; adjust AM MOD CONTROL for 100% AM as measured externally. Adjust R21 for 100% reading on MODULATION meter.

3. (202B thru 202G) - Set MOD METER switch to "AM 50%" (202D/F/G), or "AM" (202B/C/E); adjust AM MOD CONTROL for 50% AM as measured externally. Adjust R35 for 50% reading on MODULATION meter.

4. Measure Percent AM at 30% calibration mark. R35 may be readjusted to compensate between 30% and 50% as required.

NOTE: Internal modulation oscillator frequencies above 15 KC are not intended for Amplitude Modulation, only FM.

C. External AM Requirements

1. Connect an external audio oscillator to the AM-EXT. OSC. terminals; monitor its output voltage with an AC VTVM. Set frequency to 400 cps.

2. Increase applied voltage for MODULATION meter reading of 50%. Approximately 45 volts should be required.

3. (202D/F/G, only) - Increase the applied voltage for MODULATION meter reading to 100% (MOD METER switch in "AM 100% position). Approximately 100 volts should be required.

D. AM Fidelity Test (Modulation System Frequency Response)

1. Turn AC power OFF; set INT. MOD. switch to OFF, AM Control maximum clockwise, RF Control at position of normal "Red-Line" setting. On 202D/F/G, use 50% AM position if MOD METER switch.

2. Apply audio voltage from an external oscillator (-hp-200CD or equivalent) to the AM - EXT. OSC. terminals.

3. Measure the audio voltage at junction of R42 and the wire leading to V8 socket (inside RF Unit can on RF filter). Use an -HP-410B VTVM, or equivalent.

4. Increase audio oscillator voltage to obtain a "reference" reading on the MODULATION meter. This need not be an AM calibration mark, but may be any convenient scale division (over 20 Volts into 7.5KΩ would be required to reach 30% AM calibration mark).

5. Change AF frequency across the specified frequency range; re-establish "reference" on MODULATION meter using External Oscillator Amplitude Control at each frequency.

6. The total change in voltage at R42, over the specified frequency range, should remain within the specified limits (see Technical Data & Specifications of this manual, Section 1).

NOTE: 202D, serial number 2600 and below have same specifications as 202C.

VIII RF ATTENUATOR CALIBRATION

A. Output Impedance Test

1. The output impedance is checked at DC (no VSWR specification).

2. Turn power to instrument OFF.

3. Measure DC resistance, from the center conductor to ground, thru the RF OUTPUT connector. The resistance should be approximately 50Ω, or 53Ω, depending upon instrument.

B. RF Monitor Meter Adjustment (Attenuator Calibration)

1. Turn INT. MOD. switch to OFF.

2. Set frequency dial mid-range (202B/C/E to 108-216 MC range).

3. Measure RF output voltage (or power*) when terminated in 50Ω.

* NOTE: If POWER rather than voltage is measured, the tolerances must be referenced to power changes. The following limits may be used:

	Milliwatts in 50Ω		
	Min.	Normal	Max.
50 Kμ Volts ± 10%	.040	.050	.060
200 Kμ Volts ± 20%	.512	.800	1.15

4. Adjust RF control for 50 Kμ volts (0.05 mw), as measured externally.

5. Adjust R22 for "Red-Line" on the RF MONITOR meter.

6. Measure output voltage (or power*) at 20 MC intervals across the frequency band, (high frequency band of 202B/C/E). Reset to "Red-Line" before each measurement.

7. If required, readjust R22 so all readings are within ±10% of 50 Kμ V.

8. (202B/C/E, only) change to 54-108 MC band. Repeat steps 2 thru 7, adjusting R20 as R22 was adjusted above.

9. Increase MICROVOLTS/DBM dial to 200 Kμ volts. Measure RF output voltage (or power*) across each band at 20 MC intervals. Readjust to "Red-Line" for each measurement.

10. Although not specified, the voltage should remain within ±20% of the MICROVOLTS/DBM dial setting.

* NOTE: If POWER rather than voltage is measured, the tolerances must be referenced to power changes. The following limits may be used:

	Milliwatts in 50Ω		
	Min.	Normal	Max.
50 Kμ Volts ± 10%	.040	.050	.060
200 Kμ Volts ± 20%	.512	.800	1.15

IX ΔF KC ADJUSTMENT (202C/E, only)

The ΔF KC accuracy is most conveniently measured with an electronic counter, by measuring actual changes in the RF carrier frequency for each switch position.

A. Adjustment Procedure

1. Set FINE TUNING control at mid-rotation.

2. Measure RF frequency with an electronic counter.

3. Set ΔF KC switch to one extreme of rotation; note counter reading.

4. Set ΔF KC switch to opposite end of range; again note counter reading.

5. Adjust R68 such that the total change corresponds with ΔF KC dial calibration (±30 KC = 60 KC total change; ±60 KC = 120 KC total change).

6. Measure frequency at each switch position. Referenced to "0", each change should be within ±1.5% of dial reading.

X APPENDIX

A. FM Deviation Measurement

Several methods of measuring FM Deviation are described below; others are undoubtedly available at different service facilities. The method used should be that accessible to, and most convenient for, the individual technician.

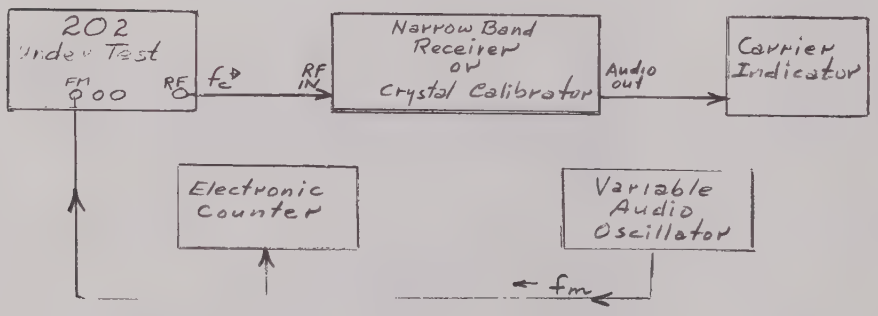
Although the Accuracy of FM Deviation is not specified on the BRC 202B/C/D/E/F/G FM Signal Generators, adjustment to better than a ±5% tolerance at 75 KC deviation* is practical; the accuracy of each method described below is commensurate with that requirement.

When adjusting the reactance modulator circuitry within the RF Unit, it will be noticed that the adjustments for FM Deviation (R47) and FM Distortion (R50) interact. Therefore simultaneous or alternate measurement of FM Deviation and FM Distortion (or Non-Linearity) is required of any test set-up.

For additional information on the methods described below, your attention is called to the references listed with each.

* Actual deviation at 240 KC deviation will be lower than MODULATION meter indication on 202B/C/D/E/F/G.

1. Bessel Zero Method (Reference: BRC Notebook #9, pages 5 & 6; BRC Notebook #34, page 5).



An equipment connection as shown above will indicate the "null" of the RF carrier as the modulation index (B) passes thru those values where the first-order Bessel Function, J_0 (B), passes thru zero. (See Figure 3, page 6 of BRC Notebook #9).

THE NARROW-BAND RECEIVER (OR CRYSTAL CALIBRATOR) USED MUST BE CAPABLE OF PASSING THE CW-RF CARRIER FREQUENCY Fc, WHILE REJECTING THE 1ST-ORDER SIDEBANDS OF THE RF SIGNAL WHEN FM'D AT AN AUDIO MODULATION RATE, Fm. THESE SIDEBANDS ARE SPACED ABOVE AND BELOW Fc AT Fc ± Fm, HENCE DICTATING THE MAXIMUM BANDWIDTH OF THE RECEIVER.

THE CARRIER INDICATOR MAY BE THE S-METER ON A NARROW BAND RECEIVER, INDICATING THE PRESENCE OF CW CARRIER AFTER REJECTION OF THE FM SIDEBANDS. IF BFO AM RECEIVER OR CRYSTAL CALIBRATOR IS USED, THE CARRIER INDICATOR MAY BE A VOLTMETER OR AN OSCILLOSCOPE INDICATING THE AUDIO OUTPUT.

THE USE OF A VARIABLE FREQUENCY AUDIO OSCILLATOR AND AN ELECTRONIC COUNTER PERMITS ACCURATE SETTING OF THE MODULATING FREQUENCY (Fm), HENCE THE FM DEVIATION AT WHICH THE RF CARRIER "NULL" WILL APPEAR. (KC DEVIATION = B x MOD. FREQ. IN KC).

THIS METHOD OF FM DEVIATION MEASUREMENT IS INDEPENDENT OF THE CENTER RF CARRIER FREQUENCY, ONLY UPON DEVIATIONS FROM Fc, THEREFORE IS EXTREMELY CONVENIENT FOR TRACKING THE FM DEVIATION ROTOR PLATES OF C33 WITHIN THE 202'S RF UNIT.

THE CHART, BELOW, GIVES VARIOUS MODULATING FREQUENCIES FOR MEASUREMENT OF SPECIFIC DEVIATIONS; THE NULL USED SHOULD BE THE ONE MOST COMPATIBLE WITH THE EQUIPMENT USED, RESULTING IN A SHARPEST POSSIBLE NULL INDICATION. FOR BEST RESULTS AND MAXIMUM ACCURACY, FREQUENCIES ABOVE THE GENERATORS NORMAL MODULATION RATES (SEE FM FIDELITY SPECIFICATION), AS WELL AS THOSE LOW ENOUGH FOR 1ST-ORDER SIDEBANDS TO FALL WITHIN THE RECEIVER'S BANDWITH, SHOULD BE AVOIDED.

FM DEVIATION	MODULATION FREQUENCY (Fm)		
	1ST NULL	2ND NULL	3RD NULL
75	31.187 KC	13.587 KC	8.667 KC
150	62.375 KC	27.173 KC	17.334 KC
* 240	99.800 KC	43.477 KC	27.734 KC

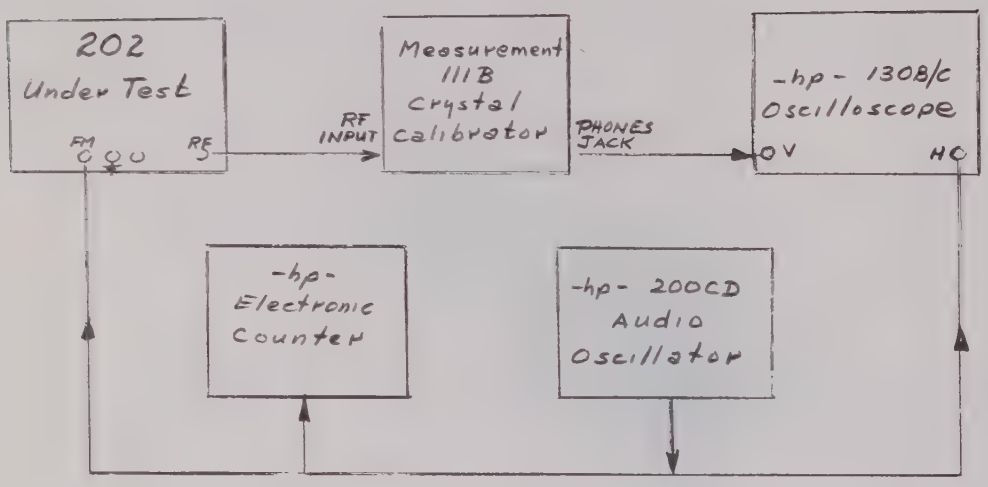
NULLS OCCUR WHEN B = 2.404, 5.5201, 8.6537, 11.7915, 14.9309, ETC.

OTHER APPROPRIATE AUDIO FREQUENCIES MAY BE CALCULATED BY:

$$Fm = \frac{\Delta F}{B} = \frac{\text{PEAK DEVIATION}}{\text{MODULATION INDEX FOR NTH-ORDER NULL}}$$

* AT OR NEAR MAXIMUM FM DEVIATION, THE ACTUAL PEAK DEVIATION WILL TYPICALLY BE AS MUCH AS 10% TO 12% LOWER THAN MODULATION METER INDICATION ON 202B/C/D/E/F/G. CONVERSELY, AT 240 KC NULL, MODULATION METER WILL USUALLY READ OFF SCALE.

EXAMPLE EQUIPMENT SET-UP



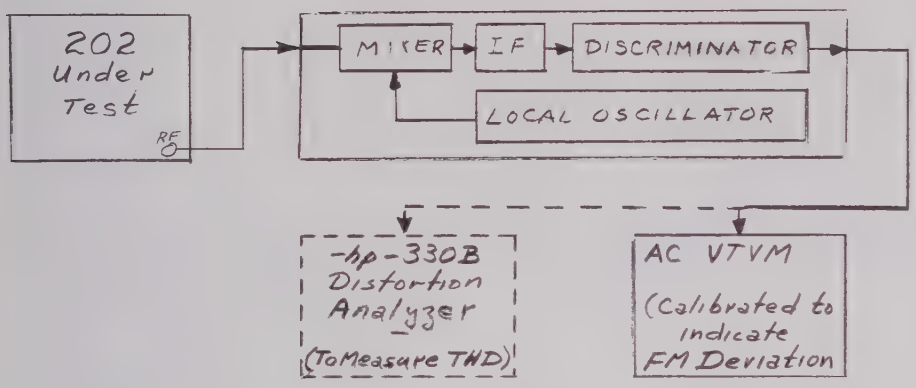
PROCEDURE:

1. SET 200CD TO DESIRED MODULATING FREQUENCY (FM) AS INDICATED ON COUNTER
2. SET 202 GENERATOR INT. MOD. SWITCH TO OFF; MOD. METER SWITCH TO FM.
3. ZERO-BEAT CW CARRIER (FM MOD. CONTROL AT MIN.) AGAINST CRYSTAL CALIBRATOR, THEN DETUNE SLIGHTLY TO OBTAIN A MAXIMUM INDICATION ON SCOPE.
4. ADVANCE FM MOD. CONTROL TO OBTAIN MODULATION METER READING OF APPROXIMATELY THE PEAK DEVIATION WHERE NULL IS EXPECTED TO OCCUR.
5. OBSERVING OSCILLOSCOPE, ADJUST FM MOD.CONTROL FOR THE BEST NULL INDICATION (USUALLY MOST SYMETRICAL PATTERN).

NOTE: TRY BOTH INTERNAL AND EXTERNAL OSCILLOSCOPE SWEEP FOR THE BEST NULL INDICATION.

6. OBSERVE READING ON MODULATION METER; ADJUST 202 GENERATOR AS APPROPRIATE.

2. Linear Detector (Discriminator) Method

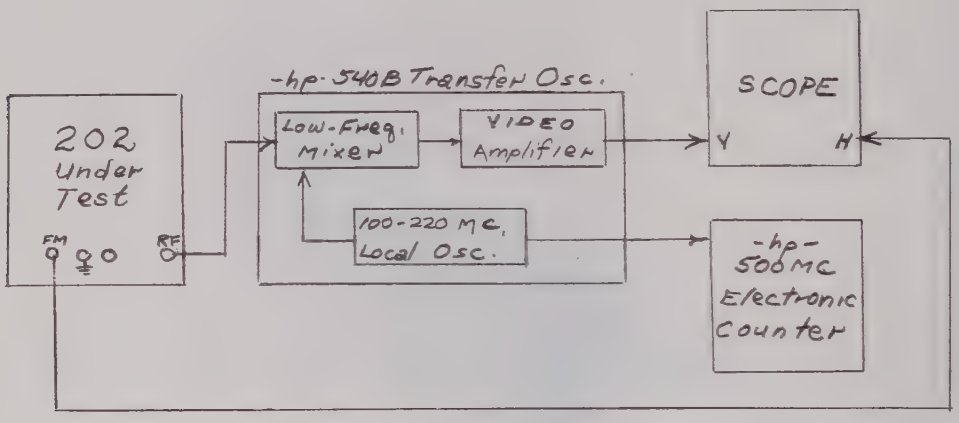


The output vs. input characteristics of the Linear Detector must be determined. This is done by applying an accurately know FM deviation, and recording the resulting output voltage reading on the AC voltmeter. The generator under test may then be calibrated by increasing its FM deviation to obtain the predetermined voltage on the AC voltmeter. The generator's meter circuitry is then adjusted to read correspondingly.

This method has the advantage of also being able to measure Total Harmonic Distortion of the recovered FM signal. For that use, however, the THD introduced by the discriminator must be negligible.

3. Transfer Oscillator and Counter Method

(Reference: Instruction Manual for -hp-540B)

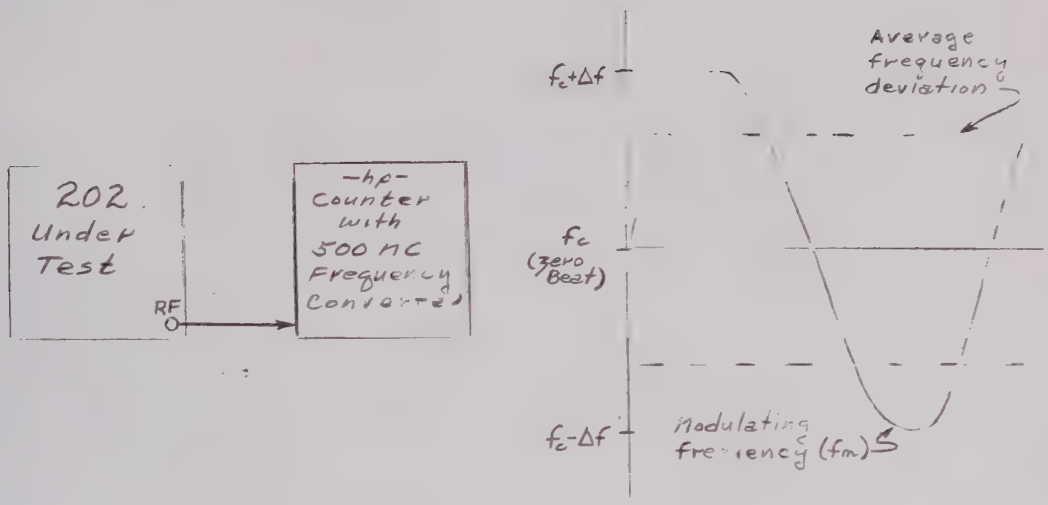


The Transfer Oscillator and Counter Method is adequately described in the Instruction Manual for the -hp-540B, as well as -hp- Application Notes #1 and #2, so will not be expanded upon here.

This method measures actual peak-to-peak deviation, which must be correlated to the peak deviation calibration of the 202 generator's meter circuitry.

It should be noted that even-order distortion of the FM signal will indicate an apparant "carrier shift", since that type of distortion causes the RF signal to deviate farther in one direction than in the other. Conversely, odd-order distortion is not apparant in this method of Deviation measurement. Adjusting the 202 generator's reactance modulator for equal deviation either side Fc minimizes even-order distortion, but does <u>not</u> assure minimum specified Total Harmonic Distortion.

4. Counter Averaging Method



Frequency Deviation is measured by counting the "average" frequency departure from the CW Carrier. To do this, the Frequency Converter is tuned to the <u>same</u> frequency as the CW Carrier (zero beat, rather than usual 10 MC difference). The Counter then counts only the "average" frequency departure from the zero beat; conversion of this average reading to peak deviation is made by multiplying by 1.5707.

The following <u>assumptions</u> are made:

(a) Frequency Converter (5253B) will operate to zero frequency differences and zero input amplitude.

(b) Gate time of Counter (5245L) is long compared to period FM modulating signal (Fm).

(c) Modulating sine-wave (Fm) has negligible distortion.

(d) Deviation is symetrical about the CW Carrier (Fc).

PROCEDURE:

1. CONNECT FREQUENCY CONVERTER AND COUNTER TO RF OUTPUT OF 202 GENERATOR UNDER TEST.
2. SET INT MOD SWITCH TO OFF.
3. ZERO-BEAT FREQUENCY CONVERTER WITH CW CARRIER FROM 202 GENERATOR. (NOTE THAT THIS IS A "ZERO-BEAT", NOT THE USUAL 10 MC "DIFFERENCE").
4. TURN INT MOD SWITCH TO FM.
5. INCREASE FM MOD CONTROL TO OBTAIN COUNTER READING SHOWN ON CHART BELOW.
6. CHECK AT 10 MC INTERVALS ACROSS THE BAND.
7. READJUST 202 GENERATOR AS REQUIRED TO OBTAIN PROPER DEVIATION READINGS.

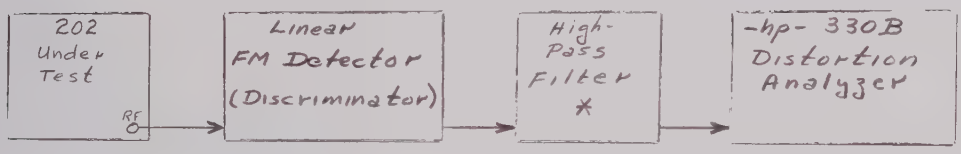
PEAK DEVIATION	COUNTER READING *			
	-12%	-5%	-0-	+5%
75 KC	-	45.358 KC	47.745 KC	50.132 KC
240 KC **	144.450 KC	-	159.150 KC	160.423 KC

* OTHER CORRESPONDING COUNTER READINGS ARE READILY CALCULATED BY MULTIPLYING DESIRED PEAK DEVIATION, AND ±5% DEVIATIONS, BY 0.6366.

** AT OR NEAR MAXIMUM FM DEVIATION, THE ACTUAL PEAK DEVIATION WILL TYPICALLY BE AS MUCH AS 10% TO 12% LOWER THAN MODULATION METER INDICATION ON 202B/C/D/E/F/G.

B. FM Distortion Measurement

(Reference: Instruction Manual for -hp-330B; also see Appendix A - 2, herein).



To measure the Total Harmonic Distortion of a Frequency Modulated signal, the THD contributed by the Linear Detector must be negligible.

Procedure:

1. Determine THD of Discriminator being used. The FM Linearity Measurement Technique in Appendix D is ideal for adjusting a discriminator for its most linear operation over the widest possible Frequency Deviation. Percent Non-Linearity may also be measured; THD will be less than that value, depending on the type of distortion present.

2. Connect equipment as shown above.
   * High Pass filter required only if Power-Line hum components from Linear Detector (discriminator) are appreciable, hence effecting THD measurements.

3. Measure combined THD of both signal generator and discriminator using convensional Distortion Analyzer Techniques. (THD of discriminator must be negligible).

4. Refer to "Reactance Modulator Adjustment and Tracking" and adjust 202 generator's reactance modulator circuitry as appropriate to minimize THD.

NOTE: If Linear FM Detector being used has significant THD, measure FM linearity of generator as described in Appendix D. Adjust reactance modulator for the <u>most linear</u> operation, <u>then</u> measure THD.

<u>CAUTION</u>: Adjustment of 202's reactance modulator for minimum THD, using a Linear FM Detector with significant THD, could result in adjustment for a complimentary minimum; ie, the introducing of the appropriate distortion products from the 202 to cancel with those of the Linear FM Detector.

C. Testing for and Minimizing R.F. Leakage

The following Test Procedure has been found to assure operation within the RF leakage specification of the 202 signal generators when shipped from the factory.

Should you suspect excessive RF leakage from your signal generator, it may be tested, and RF leakage minimized as described below.

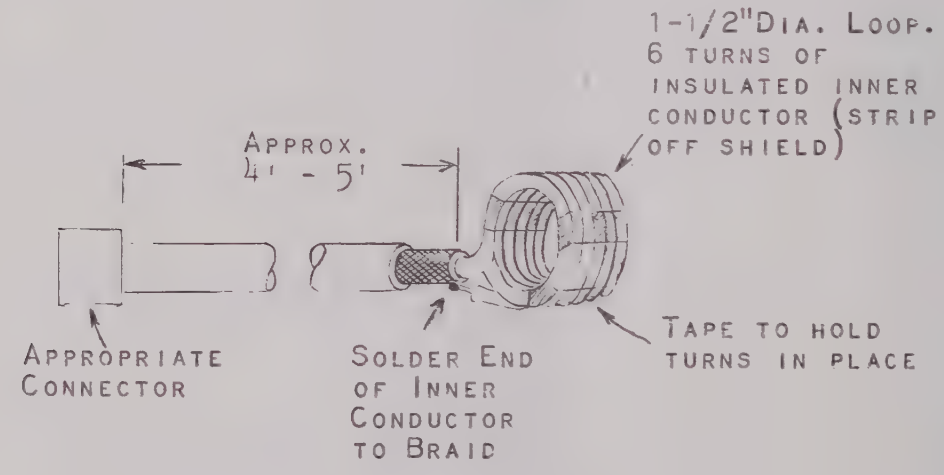
Measurement figures given must NOT be considered as "specification", but rather the normal limits normally required to obtain operation within the catalog specification of:

RF LEAKAGE: Sufficiently low to permit measurements at 0.1μV.

1. Equipment Used

(a) BRC Type 202 ( ) to be tested

(b) Loop Antenna, constructed as follows:


1-1/2" Dia. Loop.
6 turns of insulated inner conductor (strip off shield)
Approx. 4' - 5'
Appropriate Connector
Solder End of Inner Conductor to Braid
Tape to hold turns in place

(c) Receiver

(1) Frequency coverage: Desired Test Frequency between 54 MC and 270 MC.

(2) Sensitivity requirements: Must be capable of detecting and indicating on output meter, speaker, or earphones, the presence of 0.1μV when connected directly to its input terminals from a calibrated 202 ( ) output attenuator.

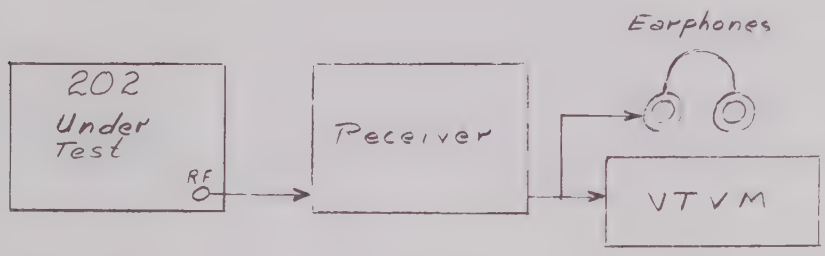
(d) VTVM, logrithmic, such as -HP-400L, for monitoring audio output of receiver.

(e) Earphones, for monitoring audio output of receiver.

2. PROCEDURE

(A) CALIBRATE RECEIVER AND OUTPUT METER.

(1) CONNECT INSTRUMENTS AS SHOWN:



(2) SET 202 ( ) TO 400 CYCLE, 50% MODULATION.

(3) TUNE RECEIVER TO DESIRED TEST FREQUENCY (USUALLY 54 MC, 151 MC, OR 200 MC); USE 202 ( ) AS SOURCE THRU A DIRECT COAXIAL CONNECTION.

(4) WITH 2.0 μV OUTPUT FROM 202 ( ) ATTENUATOR, ADJUST RECEIVER AND VTVM CONTROLS FOR A "REFERENCE" INDICATION ON THE VTVM. THIS IS BEST SET AT FULL-SCALE ON THE VTVM, SINCE THE MEASURED VOLTAGES SHOULD BE LESS THAN "REFERENCE".

(B) TEST FOR PRESENCE OF RF LEAKAGE-

(1) DISCONNECT COAXIAL CONNECTION BETWEEN 202 ( ) AND RECEIVER.

(2) ATTACH "PICK-UP-LOOP" TO RECEIVER INPUT TERMINALS.

(3) REDUCE 202 ( ) ATTENUATOR TO MINIMUM OUTPUT. (THIS IS IMPORTANT).

(4) DETECT PRESENCE OF ANY RF LEAKAGE.

WITH CABINET REMOVED, A "SEARCH" OF THE FRONT PANEL ASSEMBLY, PARTICULARLY AROUND THE SHIELDED RF UNIT, SHOULD NOT FIND RF LEAKAGE IN EXCESS OF THAT REQUIRED TO INDUCE 2 μV INTO THE "PICK-UP-LOOP" (REFERENCED LEVEL ON VTVM).

With Cabinet On, a "search" of the entire cabinet and panel will usually not find RF leakage in excess of that required to induce 0.1 μV. The only specification is: "RF leakage: Sufficiently low to permit measurements at 0.1μV". (The 0.1 μV "reference" may be set up as in paragraph 2-(a)-(4), if desired).

3. Suggestions to reduce RF leakage to within catalog spec.

(a) Locate source of any RF leakage by "searching" inside of instrument with "pick-up-loop". Pay particular attention to the following places:

(1) RF can-to-casting contact.

Caution: If can is removed, be extremely careful not to hit variable deviation rotor plates during or after removal of the can. Tap can only slightly from side-to-side to loosen, and remove straight back. Be careful not to inadvertently hit plates while can is off. For best protection, set RF frequency dial to High end of band.

Can edges bent or irregular?--Straighten and smooth to assure good continuous contact to casting. (Replacement aluminum RF can, BRC Part No. 20248; copper can used on early 202B's no longer available).

Can fits too loosely in casting?--"Roll" inside edge of can with smooth object to increase circumference.

Can edges bent inward by clamps?--Replace clamps with strap (BRC Part No. 304677); straighten or replace can to assure good contact to casting. Rub edges of can with emery cloth to assure good contact; wipe clean.

(2) Attenuator assembly - to - casting contact.

Tighten screws or replace braid (approx 3/4" of 1/8" RF shielding braid).

Note: Be sure to check calibration of RF attenuator after reassembly, if braid is replaced.

(3) RF FILTER-TO-BASE PLATE CONTACT (LARGE NUT BETWEEN RF CASTING AND FRONT PANEL).

TIGHTEN NUT, BE SURE FILTER ASSEMBLY DOES NOT ROTATE.

REPLACE (OR ADD) SHIELDING GASKET (BRC PART NO. 303222) BETWEEN RF FILTER ASSEMBLY AND BASE PLATE.

CAUTION: REPLACING OR ADDING THIS GASKET WILL REQUIRE EXTENSIVE DISASSEMBLY AND COMPLETE TESTING TO SPECIFICATIONS OF THE RF UNIT. THIS IS RECOMMENDED ONLY IF ABSOLUTELY NECESSARY TO REDUCE RF LEAKAGE FOR OPERATION OF THE INSTRUMENT WITHIN SPECIFICATIONS.

(4) CASTING-TO-PLATE CONTACT

TIGHTEN SCREWS

REPLACE RF SHIELDING BRAID (BRC PART NO. 20272).
CAUTION: (SEE CAUTION IN PREVIOUS PARAGRAPH).

NOTE: CASTING AND PLATE DO NOT NORMALLY TOUCH; THEY ARE HELD SEPARATED BY BRAID. WHEN REPLACING BRAID, ENDS MUST NOT OVERLAP, CAUSING A "HUMP". INTERLACE ENDS OF BRAID TOGETHER APPROXIMATELY 1/4". BRAID MUST BE PLACED IN GROOVE AND THEN FOLDED OVER OUTSIDE EDGE OF GROOVE.

NUMBER 33

The NOTEBOOK

BOONTON RADIO COMPANY · ROCKAWAY, NEW JERSEY
A Division of Hewlett-Packard Company

New Techniques In FM Linearity Measurement

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INTRODUCTION

It has been characteristic of the development of electronic systems and terminal equipment that effort has been continually devoted to methods of making the output of the equipment or system more faithfully reproduce the important characteristics of the input. A major consideration of this nature has been improvement in the linearity of the transfer characteristics of devices, equipment, or systems. While there are equipment and devices in which some function, other than a straight line, is wanted between the input and output, the straight line or linear relationship is by far the most common. There are several detailed motivations for this activity which have slightly different connotations in various fields of endeavor. However, it is possible to generalize on some of the factors that push development in the direction of improved linearity of transfer characteristic. In the fields of communication equipment development, extreme linearity did not become of major importance until these systems were directed toward more efficient use of the frequency spectrum. This frequently results in multiple channel transmission in which nonlinearity of the transfer characteristic causes unwanted crosstalk between the various channels.

In recent times, the use of communications type systems for the transmission of scientific, commercial, and other forms of data has become common. Since the information being transmitted has other than a subjective end result, the accuracy of data transmission is related to the linearity of the transfer characteristic. Even in the field of entertainment electronics, pressure for more faithful reproduction has been continuous. A recent development in this field, that of a system of FM Stereo Multiplex transmission, [1, 2] has forced the manufacturers of FM transmitters and receivers for the entertainment field to improve the linearity of their equipment to minimize crosstalk between the Monaural and Stereo channels of the system. One fact that should be noted is that, because of the different objectives and the different technologies which have developed around these objectives, the effects of nonlinearity in the transfer characteristic are described in many different terms.

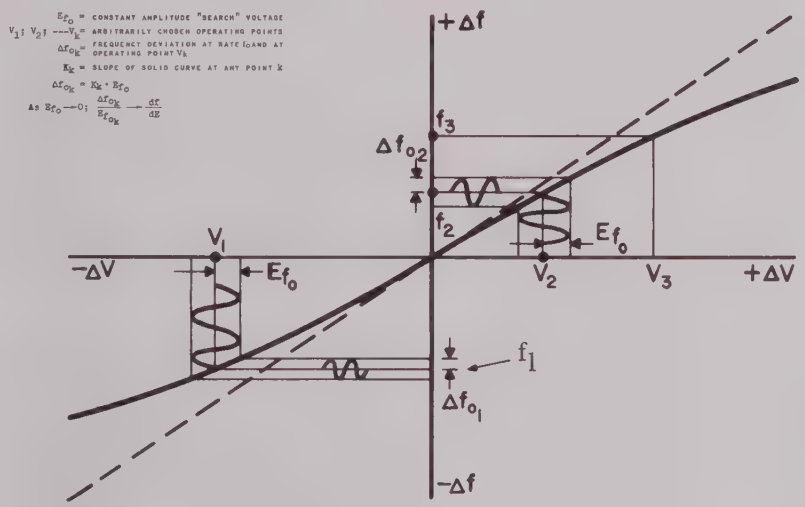

Figure 1. Transfer Characteristic with Typical Nonlinearity

GENERAL COMMENTS ON NONLINEAR DISTORTION

Before discussing the detailed techniques of measurement, it might be well to consider what we really mean by "nonlinearity", and the distortion which results therefrom. Nonlinearity, as used in this discussion, refers to that characteristic of a circuit which causes the output to be related to the input by other than a straight line function. As a result, the circuit may not be specified by linear differential equations with time as the independent variable.[3]

Many terms are used to describe distortion due to this concept of nonlinearity. In order that we may clearly understand the problems, a few definitions will be resorted to. *Nonlinear Distortion* has been defined by the IRE Standards on Circuits as "Distortion caused by a deviation from a desired linear relationship between specified measures of the output and input of a system."

NOTE: The related measures need not be output and input values of the same quantity; e.g., in a linear detector, the desired relation is between the output signal voltage and the input modulation envelope."

Other names used to describe the effects of nonlinear distortion are *Amplitude Distortion, Waveform-Amplitude Distortion,* and *Harmonic Distortion.* In addition to these names, there are specific means of measuring nonlinearity among which are *Total Percent Harmonic Distortion* and *Inter-*

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modulation Distortion. It should be stressed, that while there may be different names for the effects of nonlinearity and many different standard ways of expressing the effects numerically, all of these related types of distortion stem from the same nonlinearity of the transfer characteristic as discussed above.

The casual reader of papers on distortion in the field of sound reproduction, may be left with the feeling that, somehow, there is a large difference between intermodulation distortion (IM) and total percent harmonic distortion (HD). While there may be advantages in one system of measurement or the other, when it is desired to relate the numerical result of the measurement to the subjective response of the listener, it should be remembered that finite results in either an IM or HD measurement occur due to nonlinearity of the transfer characteristic, and measurement by either method may be analytically related for any specific shape of curve. Further discussion of this may be found in Reference 4.

A related case occurs in the measurement of deviation from a frequency modulated source by zero beating another RF source with the peak excursions of the FM carrier. Then, the frequency of this source, for zero beat with the upper and lower FM excursions, is measured and compared with the unmodulated FM carrier. Equality of these differences has sometimes been taken as evidence of good linearity. That this is not so, can be seen in Figure 1. Since voltages V_1 and V_3 have been chosen equal and opposite, and the resulting frequencies, f_1 and f_3, are equidistant from the origin, the condition of the beat frequency measurement is described. However, the transfer characteristic shown is anything but linear. It is true, though, that the symmetry about the unmdoulated carrier, so measured, indicates a predominance of odd-order harmonic distortion. Asymmetry about the unmodulated carrier is a strong indication of even-order distortion.

Many observers have commented on this so called "FM carrier shift" or difference in frequency between the average carrier frequency (when modulated) and the unmodulated carrier. This is due to the "DC" or constant term which appears in a Fourier expansion of the polynomial representation of a transfer function with even-order curvature (second harmonic or "squared" terms), and is a reliable indication of the presence of even-order harmonic distortion; usually second harmonic.

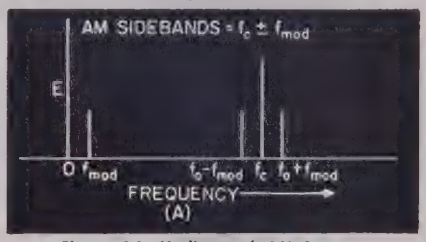

Figure 2A. Undistorted AM Spectrum

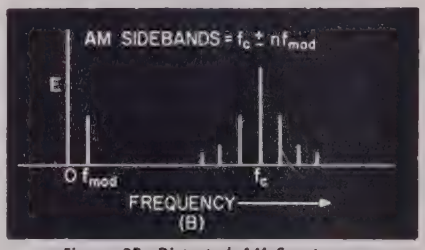

Figure 2B. Distorted AM Spectrum

FM SIGNAL GENERATOR MEASUREMENT

In the development of the Type 202J and 202H FM Signal Generators, Boonton Radio Company faced a specific aspect of the nonlinearity problem. Since we were designing a linear frequency modulator, it was necessary that we be able to measure the transfer characteristic nonlinearity of this modulator to a high degree of precision. An obvious way to accomplish this would be to measure the results of frequency modulation through a perfectly linear demodulator. However, it is somewhat difficult to produce the perfect demodulator without having a perfect modulator with which to measure it. Therefore, another method was needed. Let us examine some common techniques.

In the simple case of amplitude modulation, it is possible, by means of a suitable wave analyzer, to measure the frequency spectrum resulting from the modulation process. If the modulating signal is free of distortion and the modulation process is perfectly linear, the resulting spectrum in the vicinity of the carrier will contain only the carrier and the two sidebands, separated from the carrier by the modulation frequency as seen in Figure 2A. If nonlinearity of the transfer characteristic exists, the results may be as shown in Figure 2B. Here, the appearance of sidebands, separated from the carrier by integral multiples of the modulating frequency, is not only qualitative evidence of nonlinear distortion, but affords a measure of this distortion if the amplitudes of all the sidebands relative to the carrier are determined.

In the FM case, for deviations and modulation frequencies for which the modulations indices, defined as

$$m = \frac{\text{peak deviation}}{\text{modulating frequency}},$$

are appreciably greater than unity (the usual case), the resulting frequency spectrum becomes exceedingly complex, even for an undistorted modulation process.[5] In the presence of nonlinearity of the frequency modulator, the spectrum becomes even more complex; thus ruling out spectrum analysis as a simple means of measuring nonlinearity.

A second method for measuring a frequency modulator transfer characteristic is possible, if the modulator is capable of operation at dc. This method consists of introducing a known increment of modulating voltage and measuring the resulting frequency increment. Its precision is limited by the stability of the carrier frequency in the absence of modulation and the ability to read small increments in voltage and frequency precisely. Modern measuring equipment has solved the latter two problems, but not the former.

In addition to the matter of precision, it was desired by BRC to be able to make adjustments on the frequency modulator for minimum nonlinearity as a result of an instantaneous display of nonlinearity of the frequency modulator. This same need is felt by designers and manufacturers of FM transmitters and receivers.

DEVELOPMENT OF THE METHOD

In order to best understand the method to be described, let us avoid specific numbers or circuits, and resort to a general discussion of a circuit which relates a change in voltage to a change in fre-

quency or vice versa. This covers the general case of frequency modulators and demodulators. Reference to Figure 1 will show the transfer characteristic of such a circuit. The horizontal axis represents changes in voltage and the vertical axis changes in frequency. Either may be the independent variable for purposes of our discussion. Shown dotted is a reference straight line which passes through the origin, as does the arbitrary nonlinear curve. Our problem is to measure the departure of the actual curve from the ideal straight line. A corollary to this problem is to define the initial relationship of the straight line to the actual curve. This may be done in several ways. It has been common for people in the telemetry and data transmission field to be interested in the instantaneous departure of their actual transfer characteristic from the ideal straight line. This stems from their historical use of such characteristics to transmit simple analog information. Several ways have been used to express this, but a common one is illustrated in the performance specification of the BRC 202J Telemetry Signal Generator. Here, the reference straight line chosen is that line for which the rms sum of the differences between the actual curve ordinates and the straight line ordinates is a minimum. Another method would be to have the average departure a minimum, or the peak departure a minimum. For small, low order, nonlinearities, there is little difference between these cases.

Figure 1 shows that one way to describe the departure of the curve from the straight line is to measure a large number of individual ordinates of the actual curve, subtract them from the ordinates of the straight line, and report the differences in tabular or curve form. This type of data would result from a point-by-point measurement of the characteristic, using an electronic counter to measure the frequency and a precision incremental voltmeter for the voltage axis. This technique is not instantaneous, even when automated, and yields more data than can be conveniently digested quickly.

It is also evident in Figure 1, that if the slope of the actual curve could be compared, at any point, with that of the straight line, a relationship covering the nonlinearity could be readily developed. Pursuing this line of reasoning, it should be possible to make an incremental measure of the slope of the curve by introducing a small amplitude

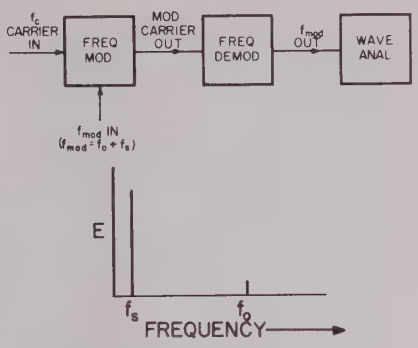

Figure 3A. Linear AM and FM Demodulator with Output Spectrum

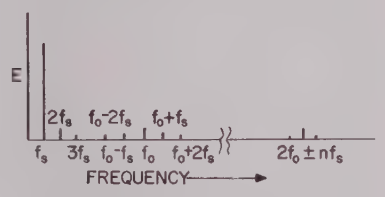

Figure 3B. Nonlinear FM Demodulator — Linear FM Modulator Spectrum

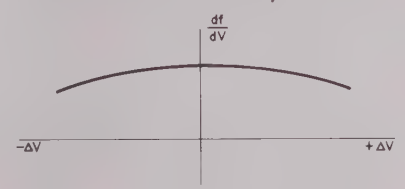

Figure 3C. Plot of df/dV of Figure 1

sine wave of voltage, E_{f_o}, (if voltage were the desired independent variable) superimposed on a direct voltage. The direct voltage may then be varied. If the resulting frequency variation, due to the small constant amplitude search voltage E_{f_o} were measured at each value of V, and plotted as a function of V over the entire range of interest of the voltage axis, a plot of the varying slope of the actual transfer characteristic would result. The extent to which this departs from the slope of the straight line, is a measure of the nonlinearity of the transfer characteristic. This method sounds relatively laborious, until it is realized that this can be done dynamically by allowing V to vary over the desired dynamic range at a sinusoidal rate, f_s. The slope of the transfer characteristic can be plotted on an oscilloscope by driving the vertical axis with an amplitude proportional to Δf and the horizontal axis with a voltage proportional to V, and varying at rate f_s.

Let us now consider the case of a linear frequency modulator and frequency demodulator, to which we will apply the two test voltages, E_{f_o} and V_{f_s}, with the understanding that V_{f_s} is of such magnitude as to sweep through the entire dynamic range of interest and that E_{f_o} is very much smaller than V_{f_s}, typically one-tenth as great. This situation is shown in Figure 3.

As might be expected, the output spectrum of the linear demodulator driven by the linear modulator is simply E_{f_o} and V_{f_s}, with the amplitude relationship established by the input. If we now further assume that the frequency modulator is linear, but that the frequency demodulator is nonlinear (curve of the nature shown in Figure 1), we realize that if E_{f_o} were to be plotted as a function of V_{f_s}, we would approximately plot the slope of the transfer characteristic being studied, namely, that of the assumed nonlinear demodulator. Therefore, we may write that $\Delta f = \frac{df}{dV}(E_{f_o})$, where df/dV is recognized as the slope of the transfer characteristic in Figure 1.

Another view of the same phenomena is shown in Figure 3B. This shows the output spectrum of the nonlinear demodulator driven by the linear modulator, and with the input as assumed previously. The output spectrum is now far more complicated than in the linear case (Figure 3A), consisting not only of V_{f_s} and E_{f_o}, but also of integral multiples with decreasing amplitude of both f_s and f_o, and sum and difference frequency terms resulting from the nonlinearity of the transfer characteristic.

Figure 3C shows the df/dV curve as determined by plotting the amplitude of Δf from the demodulated output as a function of V_{f_s}. This would be an accurate plot of the transfer characteristic slope if the magnitude of E_{f_o} in the input were made vanishingly small compared to V_{f_s}. For the cases studied by the writer, this approximation is entirely satisfactory if $V_{f_s}/E_{f_o} \approx 10$. It should be emphasized that Figure 3C and the spectrum plot of Figure 3B contain the same information concerning the transfer characteristic nonlinearity, but displayed in a different manner. The question now is, how may we simply achieve such a display?

The block diagram of Figure 4 shows the introduction of a bandpass filter which accepts f_o and the significant sidebands about it due to f_s, and the display of the resulting carrier envelope on the vertical axis of an oscilloscope. The horizontal axis is driven by the initiating V_{f_s} from the input of the frequency modulator. Figure 5 shows a

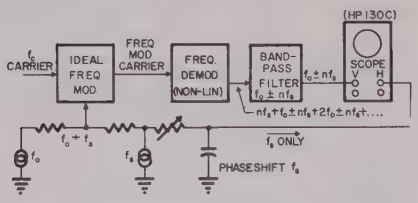

Figure 4. Block Diagram of Circuit Used to Provide Instantaneous Display of Transfer Characteristic Change of Slope

typical result. Since we have passed our demodulated signal through a bandpass filter, the upper and lower section of the envelope presented to the oscilloscope must be symmetrical; therefore, we may select either for consideration. (The final equipment shown in Figures 10 and 11 chose the negative half of the envelope for display.) Where the amplitude of the f_s sidebands about f_o is very low, as would be true of a highly linear circuit, the resulting departure of the oscilloscope trace from a rectangle is small. Since we may ignore half the envelope, it is possible to offset the centering of the oscilloscope and greatly expand either half of the display. If an oscilloscope, such as the Hewlett-Packard 130C, is used, linearity of the display will be maintained for an expansion of half the envelope by 10 times. This permits measuring changes in slope down to about 0.1% of one-half the envelope.

The departure of the envelope in this display from a reference value (chosen as the slope at the origin of Figure 1, and appearing on the vertical center line of the oscilloscope display

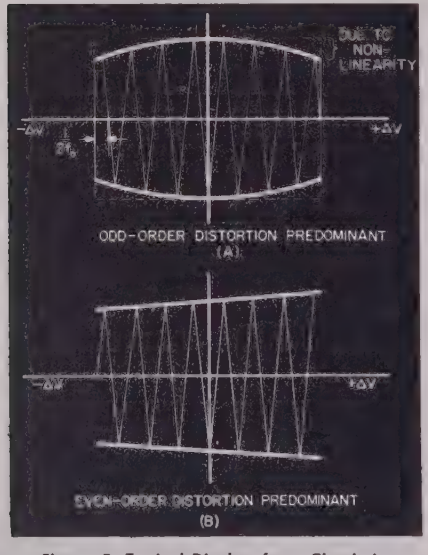

Figure 5. Typical Display from Circuit in Figure 4.

in Figure 5), is a direct measure of the change in slope of the transfer characteristic. Therefore, the slope of this curve is approximately the second derivative of the transfer characteristic. If the envelope of Figure 5 shows symmetry about the vertical center line of the trace (Figure 5A), it can be shown that this is a result of odd-order (3rd, 5th, etc.) harmonic distortion. If the envelope is asymmetrical about the vertical center line and has mirror image symmetry about the horizontal center line (Figure 5B), the distortion is largely even-order (2nd, 4th, etc.) Thus, it can be seen, that much information is contained in the displays of Figure 5, produced by the circuit of Figure 4.

Up to this point in the discussion, we have been assuming a linear modulator. The reader may well comment, "This is all fine, but where do I get the perfectly linear modulator?" The technique illustrated in the block diagram of Figure 6 shows a method of "synthesizing" an FM signal, modulated simultaneously by two frequencies (f_o and f_s), in which sidebands of f_s around f_o are not produced, even though the individual signal generators have some nonlinear distortion. The technique used is borrowed directly from the receiver practice of mixing an incoming signal with a local oscillator and amplifying at a fixed intermediate frequency before frequency demodulation is performed. Let us then consider the linearly demodulated spectrum produced by modulating either signal generator by a single frequency, remembering that one generator is modulated by f_s and the other by f_o.

The output spectrum from a perfect demodulator driven by a nonlinear modulator with single frequency input would consist of the original modulating frequency and integral multiples of this frequency, generally in decreasing magnitude. Since the two frequencies f_s and f_o do not simultaneously exist in either frequency modulator, it is not possible to produce sum and difference frequencies in the linearly demodulated output. (See Figure 7.) When the carrier frequencies (f_{C_1} and f_{C_2}) generated by the two FM sources (one modulated by f_s and the other by f_o) are mixed at RF (Figure 6), and the difference carrier frequency is amplified by a suitable selective amplifier, the instantaneous frequency in the selective amplifier is the simple arithmetic difference

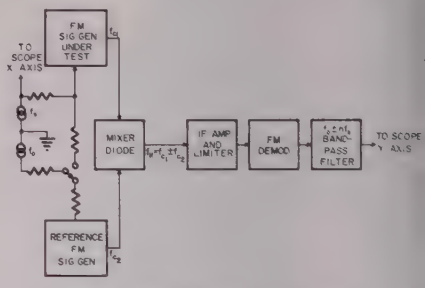

Figure 6. Block Diagram of Circuit for Synthesizing Perfectly Linear Modulation

of the instantaneous frequency modulated sources. Thus, no sum and difference frequencies of the modulating signals f_o and f_s appear in the FM signal at average frequency, f_{if}.

Now, following the technique discussed previously, let us introduce a bandpass filter centered on f_o in the output of the demodulator. The bandwidth of this filter must be wide enough to accept the significant sidebands of f_s about f_o. For the cases studied by the writer, acceptance of sidebands up to the 3rd is sufficient. This bandpass is shown by dotted lines in Figure 7. It will be seen that this filter eliminates f_s and all of the distortion products due to the nonlinearity of the frequency

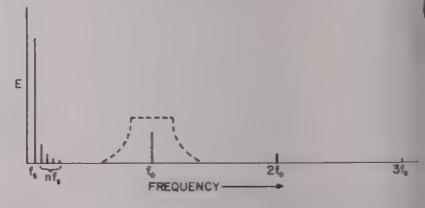

Figure 7. Demodulator Output Spectrum of nf_s and nf_o with Superimposed Bandpass Filter — Linear Case

modulators in the individual signal generators which produce the difference frequency, f_{if}.

Now, let us consider the effect of nonlinearity in the frequency *demodulator* when driven by a signal generated by the circuit of Figure 6. It is evident from the previous discussion, that the spectrum will consist not only of the components shown in Figure 7, but of sidebands about f_o and its harmonics spaced by nf_s. (See Figure 8.) If the output of the bandpass filter is connected to an oscilloscope, as discussed previously, an envelope, similar to that of Figure 5, will be seen. Thus, we have a technique for using two signal generators of finite modulator nonlinearity to synthesize an apparently distortionless signal which may then be

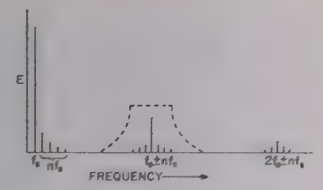

Figure 8. Demodulator Output Spectrum of nf_s and nf_o Including nf_s Sidebands About f_o — Nonlinear Case

used to measure the nonlinearity in a frequency demodulator.

To avoid the necessity of offsetting the axis of the oscilloscope display and expanding the scale to look at small deviations of the envelope from rectilinearity, it is possible to eliminate the carrier with a linear amplitude demodulator. The composite block diagram of Figure 9 shows the application of a simple linear AM detector followed by a low-pass filter to eliminate the carrier, f_o, from the display. The output from the linear detector will be a direct current component proportional to the peak amplitude of f_o, together with the envelope produced by the nf_s sidebands beating with the carrier. The percentage change in slope, compared to a straight line, may be read by expressing the peak value of the demodulated envelope as a percentage of the dc component (which is proportional to the peak value of f_o).

If the output of the AM detector and nf_s low-pass filter is read on an averaging meter, an average value of the percent change in slope will be read. For the cases studied by the writer, the amplitude of the significant harmonics (2nd and 3rd) of f_s has been relatively low, so that the value read by an rms calibrated, average reading meter (such as the Hewlett-Packard 400D) closely approximates the rms value of the departure of the slope of the transfer characteristic from the constant slope of the ideal straight line. Since the departure of the transfer characteristic of Figure 1 from a straight line necessitates a change in the slope of the transfer characteristic, it is seen that these are related effects. Calculations have shown that the numerical values for percent change in slope, as described above, are always less than the values for percent departure of the transfer characteristic from a straight line. The specific relationship depends on the actual shape of the curve. However, for transfer characteristics experienced in FM modulators and demodulators, the ratio of percent departure from a straight line to percent change in slope from that of a straight line varies from 1/2 to 1/3. Thus, a measurement of 1% change in slope insures a departure of the transfer characteristic from a straight line of less than 1%.

Figure 9 shows a composite block diagram of the entire setup with a few additional features. Instead of separately modulating the Signal Generator under test and the reference Signal Generator with f_s and f_o respectively, if the Signal Generator under test is simultaneously modulated by f_s and f_o (by switching S_1) the change in slope of the frequency modulator of the Signal Generator under test will be superimposed upon that of the FM demodulator. Thus, if the individual ordinates of the display produced by the block diagram in Figure 9 are noted for the case of separate modulation, and then determined for the case of simultaneous modulation of the Signal Generator under test, the algebraic difference of these ordinates will produce a curve which is due to the nonlinearity of the Signal Generator under test only, and does not depend upon that of the frequency demodulator. Note that when switching f_s from one generator to the other, the horizontal polarity of the display is reversed.

Thus, we have developed a circuit and measuring technique which will measure the change in slope of a frequency modulator largely independently of the demodulator, as well as the change in slope of the demodulator independently of the frequency modulator. Many additional refinements are possible to the basic circuit of Figure 9 to speed up the measurement. Some of these features are:

1. An ac voltmeter, calibrated directly in kc deviation may be connected to the output of the discriminator. Methods of calibration are covered in Reference 5.

2. A dc meter may be used to indicate the level of the demodulated magnitude of f_o.

3. If the dc meter indication is kept constant, an ac meter on the output of the nf_s bandpass filter may be calibrated directly in percent change in slope.

4. Switching may be added to facilitate the alternate connection of f_s and f_o to separate or to a common signal generator (S_1 in Figure 9).

A photograph of such equipment, used in the production test of BRC 202H and 202J Signal Generators, is shown in Figure 10. It should, of course, be noted that the FM demodulator used must be preceded by an excellent amplitude limiter, or spurious effects will occur which are not measures of the true nonlinearity of the frequency modulator or demodulator. In the equipment shown, normal circuits have proven satisfactory. The particular discriminator used was centered at 21 mc and is approximately 5 mc wide, so that the resulting change in slope for deviations of ±150 kc is less than 0.2% peak. This high degree of linearity permits direct measurement of signal generator nonlinearity without the need for calculation. In addition, it permits direct measurement of total percent harmonic distortion of a signal generator by the connection of a good distortion analyzer (such as the Hewlett-Packard 330B) to the output of the discriminator.

Figure 11 shows several cases of nonlinearity displayed by the BRC production test equipment shown in Figure 10. The scale calibration is such

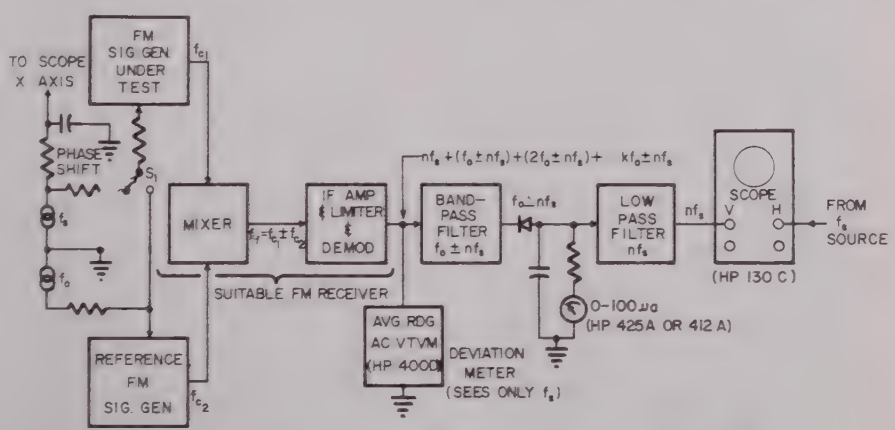

Figure 9. Block Diagram of Circuit Used to Obtain Change of Slope Display

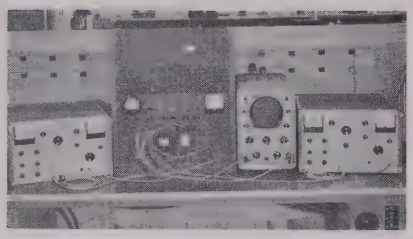

Figure 10. BRC Production Test Station

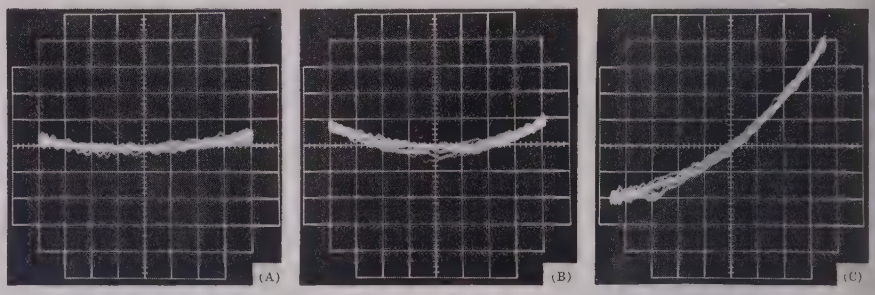

Figure 11. Typical Change of Slope Displays Obtained from Setup in Figure 10.

that a peak-to-peak amplitude of 1.0 cm represents 1% total change in slope.

In this particular equipment, $f_s = 50$ cps and V_{f_s} is set for 150 kc deviation. A frequency of 100 kc was chosen for f_o and E_{f_o} is set for about 15 kc deviation. Almost any other choice of frequencies may be made, subject to the availability of suitable filters; however, f_o should not exceed 100 kc.

Figure 11A shows the change in slope of the BRC production test discriminator alone. This discriminator, plus a properly adjusted 202J Signal Generator, is shown in Figure 11B. Figure 11C shows a typical case of incorrect setting of the operating point of the reactance tube in a 202J Signal Generator. With this display, it is a simple matter to readjust the bias for minimum nonlinearity of the frequency modulator. Resulting changes in carrier frequency must be corrected. A properly set up 202J Signal Generator will show a percent change in slope of less than $\pm 1\frac{1}{2}\%$.

EQUIVALENT FIELD TECHNIQUE

It is possible to utilize the method described above without the complex, specialized equipment shown in Figure 10. This equipment was designed for a particular production test operation and has many features unnecessary to the person who must occasionally adjust a frequency modulator or demodulator for maximum linearity. The circuit of Figure 12 permits the application of our method with readily available commercial instruments. The only special piece of apparatus required is the $f_o \pm nf_s$ bandpass filter and the nf_s low-pass filter which may be readily constructed from the values shown in Figure 12. Should a suitable oscilloscope (such as the Hewlett-Packard 130B or 130C) be available, the refinement of the amplitude demodulator and the nf_s low-pass filter may not be needed.

For FM demodulators of high output impedance, a good electronic voltmeter (HP 400D, etc.) may be used to provide high input and low output impedance and some attenuation (in 10 db steps). Many telemetry receivers have cathode follower or other low impedance outputs which will drive the 4K ohm bandpass filter impedance adequately. To avoid nonlinearity caused by the voltmeter diodes, the diodes should be shorted out.

The nf_s low-pass filter includes a resonant impedance transformer ($Q \leqq 5$) to give a high enough level to the AM demodulator to insure good linearity of the change of slope display. Its output should be checked by the oscilloscope envelope method to insure accuracy.

While it is desirable that the frequency demodulator used be sufficiently linear to permit measuring the signal generator nonlinearity directly, this may be difficult to realize in the field. Therefore, it is essential that the two signal generator method (separately modulated) of Figures 6 and 9 be employed in order to measure or minimize the nonlinearity of the frequency demodulator. After adjustment for minimum nonlinearity, a "grease pencil" trace may be made on the oscilloscope reticule of the nonlinearity (expressed as percent change in slope) of the demodulator. Switching to simultaneous modulation of the signal generator being adjusted will alter the pattern, due to the nonlinearity of this generator. Allowance must be made for the pattern reversal on the horizontal axis, or the polarity of f_s applied to the generator under test may be reversed. It is then necessary to readjust the reactance tube bias of the signal generator to most nearly equal the change of slope curve of the demodulator traced on the oscilloscope reticule. It is obvious that the method becomes inaccurate when the nonlinearity of the demodulator is large compared to that of the signal generator.

RECEIVER ADJUSTMENT

The equipment setup of Figure 12, with one significant addition, can be

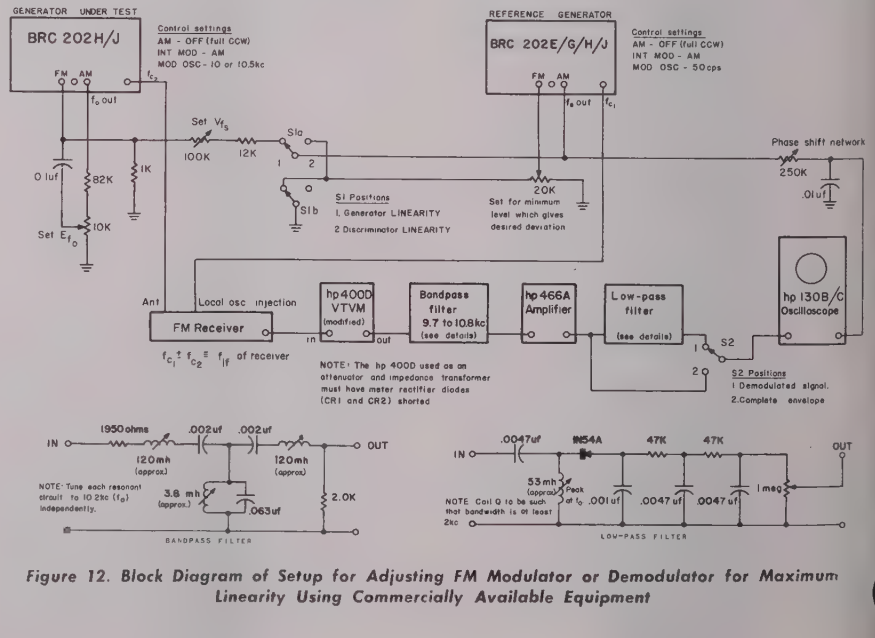

Figure 12. Block Diagram of Setup for Adjusting FM Modulator or Demodulator for Maximum Linearity Using Commercially Available Equipment

used to adjust an FM demodulator for maximum linearity, even in the absence of the complete FM receiver. Substitution of a suitable commercial RF mixer for the receiver front end, followed by one or two of the BRC 230A Signal Generator Power Amplifiers (which provide 24 to 30 db gain) will frequently permit proper drive levels to a limiter and demodulator circuit under development. This use of the 230A facilitates the detailed experimental evalution of an FM limiter and demodulator prior to the availability of the rest of the receiver. Having substituted the 230A and a commercial mixer for the receiver front end, it is only necessary to proceed as previously outlined. In order to minimize the effects of residual amplitude modulation in the FM signal generator, it is desirable to operate the level of the beating signal generator 5 to 10 db lower than that of the frequency-modulated generator. This allows the diode mixer to minimize the unwanted amplitude envelope due to the tuned carrier bandpass circuits in the signal generator.

When displaying the nonlinearity of the demodulator, it is desirable to vary the carrier level of the generator under test with its attenuator to show that proper amplitude limiting is provided ahead of the frequency demodulator.

In setting up the equipment of Figure 12, the use of 202H and J Signal Generators reduces the needed external instruments over that required with other signal generators. Since the 202H and J (and also 202E, G, etc.) include an AF oscillator, it is possible to use this oscillator for the search voltage (E_{f_0}) and the sweep voltage V_{f_s}. The connections of the AM and FM terminals to accomplish this are shown in Figure 12. It is extremely important, though, to keep the AM controls full counterclockwise to avoid unwanted AM of either carrier.

The filter bandwidth is adequate to be used with both the 10 kc AF of the 202H and the 10.5 kc of the 202J.

When aligning a 202H, after following the procedure to achieve minimum nonlinearity, if the demodulator is appreciably more linear than the 202H, a total percent harmonic distortion reading may be meaningfully made.

CONCLUSION

In conclusion, let us summarize the following points:

1. The general definition of distortion resulting from transfer characteristic nonlinearity has been given, together with qualitative relationships between various types of nonlinear distortion and methods of expressing them.

2. A technique for producing an essentially linear frequency-modulation signal from two relatively imperfect signal generators has been described. This technique permits the accurate measurement of demodulator nonlinearity in the presence of practical levels of modulator nonlinearity in terms of the departure of the slope of the transfer characteristic from that of a reference straight line. Having achieved this measurement, it is then possible to measure the nonlinearity of frequency modulators by calculating out, or eliminating, the nonlinearity of the demodulator in the composite display. This method results in an instantaneous dynamic display which facilitates adjustment of either the modulator or demodulator.

3. An equipment setup has been shown which permits the application of the technique in the field with commercially available test equipment, presuming a suitable frequency modulation receiver or demodulator is available.

Similarity of the techniques discussed here to the Intermodulation Distortion method of C. J. LeBel[7] will be seen. However, the numerical results of LeBel's method depend critically on the amplitude ratio of the two signals, while, in the change of slope method, it is only necessary that E_{f_0} be sufficiently small to truly measure slope. V_{f_s} is chosen for the desired deviation being studied.

REFERENCES

1. Van Duyne, J. P., "A Modulator for the New FM Stereo System", BRC Notebook No. 30.
2. Appendix to FCC Docket 13506, "Amendment of Part 3 of the Commission's Rules and Regulations to Permit FM Broadcast Stations to Transmit Stereophonic Programs on a Multiplex Basis."
3. "IRE Standards on Circuits: Definitions of Terms in the Field of Linear Varying Parameter and Nonlinear Circuits", IRE Standard, 53 IRE 4.S1, Proc. of the IRE, March 1954, page 554.
4. Warren, W. J. and Hewlett, W. R., "An Analysis of the Intermodulation Method of Distortion Measurement", Proc. of the IRE, April 1948, pages 457-466.
5. Wachter, J. E., "A Method of Measuring Frequency Deviation", BRC Notebook No. 9, page 5.
6. Hilliard, J. K., "Intermodulation Testing" Electronics 19.7, July 1946, page 123.
7. LeBell, C. J., "A New Method of Measuring and Analyzing Intermodulation", Audio Engineering 35.7, July 1951, page 18.

BRC APPOINTS FOUR NEW ENGINEERING REPRESENTATIVES

Boonton Radio Company recently announced the appointment of four new east-coast engineering representatives: Horman Associates, Inc., RMC Sales Division and Robinson Sales Division of Hewlett-Packard Company, and Yewell Associates, Inc.

Horman Associates, Inc. has its headquarters in Rockville, Maryland, a suburb of Washington, D.C., and a branch office in Baltimore. RMC has two offices: the main office in New York City, and a branch office in Englewood, New Jersey. Robinson Sales Division has three offices, with headquarters located near Philadelphia in West Conshocken, Pennsylvania, and branch offices in Camp Hill, Pennsylvania, and Asbury Park, New Jersey. Yewell Associates, Inc. has its main office in Burlington, Massachusetts, with branches in Middletown, Connecticut, and Poughkeepsie, New York.

With the appointment of RMC, Robinson, Horman, and Yewell, BRC expects to further improve customer services to its many customers. "Chuck" Quinn, who previously had been handling a portion of this territory from the factory, will still be on hand to assist customers with their special application problems.

The complete story on our new representatives, including an introduction to their key personnel, will be presented in the "Meet Our Representatives" series which will be resumed in the next issue of the Notebook. Meantime, we urge our customers in the areas served by these new representatives to call or write them for information about BRC equipment.

A complete list of addresses and telephone numbers for all BRC Engineering Representatives appears on page 8 of this issue.

EDITOR'S NOTE

BRC Assumes Divisional Status

Boonton Radio Corporation, a subsidiary of the Hewlett-Packard Company since 1959, assumed divisional status November 1, 1962. At that time, BRC's name was changed to Boonton Radio Company.

The conversion of BRC to a division of the Hewlett-Packard Co. is a part of an over-all program to achieve greater flexibility of the entire HP organization and to improve operating efficiency. This change will in no way affect BRC policies or product line, but will permit us to offer improved and expanded services to our customers.

Mr. William D. Myers, formerly manufacturing manager of HP's Microwave Division in Palo Alto, has been named general manager of the new Boonton Radio Division. Mr. Myers joined HP in 1944 as a development engineer and has since held a number of executive positions, including manager of quality-control engineering.

A native of San Jose, California, Mr. Myers is an electrical engineering graduate of Stanford University and a senior member of the Institute of Radio Engineers.

William D. Myers

BRC Wins "New Good Neighbor" Award

Boonton Radio Company was one of ten winners in the third annual "New Good Neighbor" contest, a state-wide contest sponsored by New Jersey Business Magazine, a service of the New Jersey Manufacturers Association. Nominations for the contest are made by the mayors of the communities in which new buildings are located. Winners are selected by a panel of noted business and civic leaders and architects. Points considered in the judging are: the general attractiveness of the building and its economic value to the community, and the company's overall community relations approach and effectiveness.

BRC is indeed happy to have been selected a winner in the contest and is proud of its "good neighbor" role in the community.

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BOONTON RADIO COMPANY

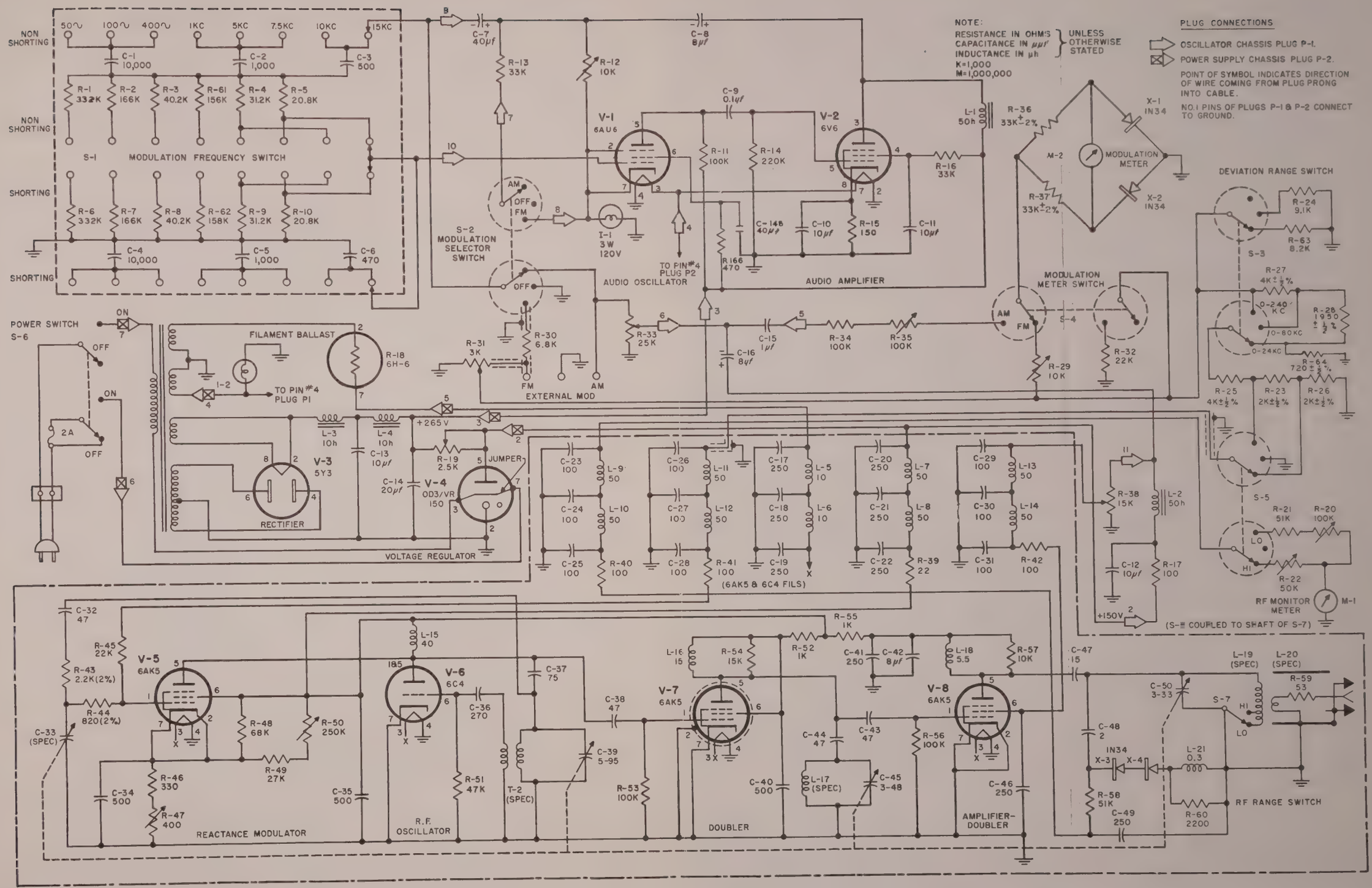
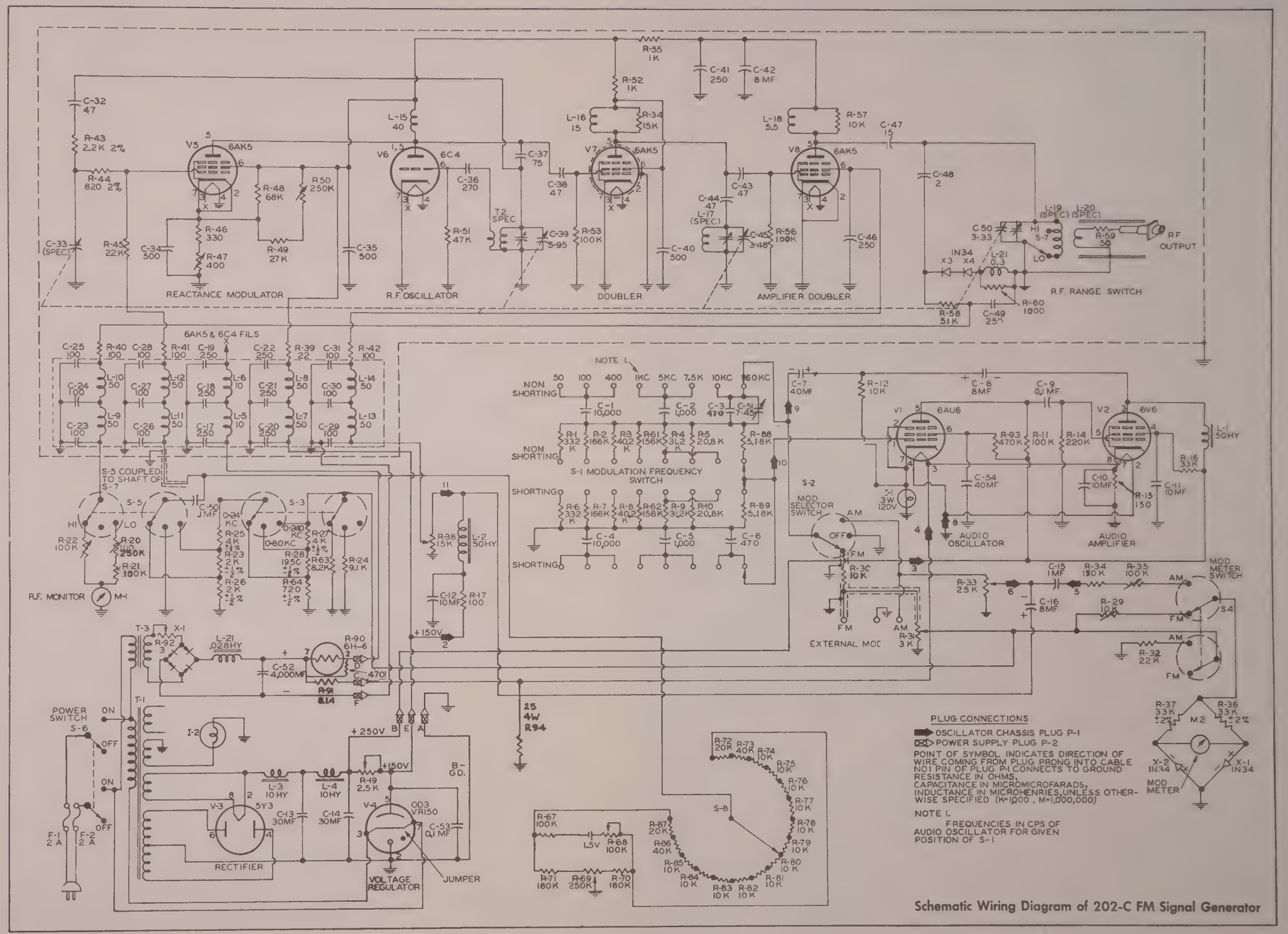
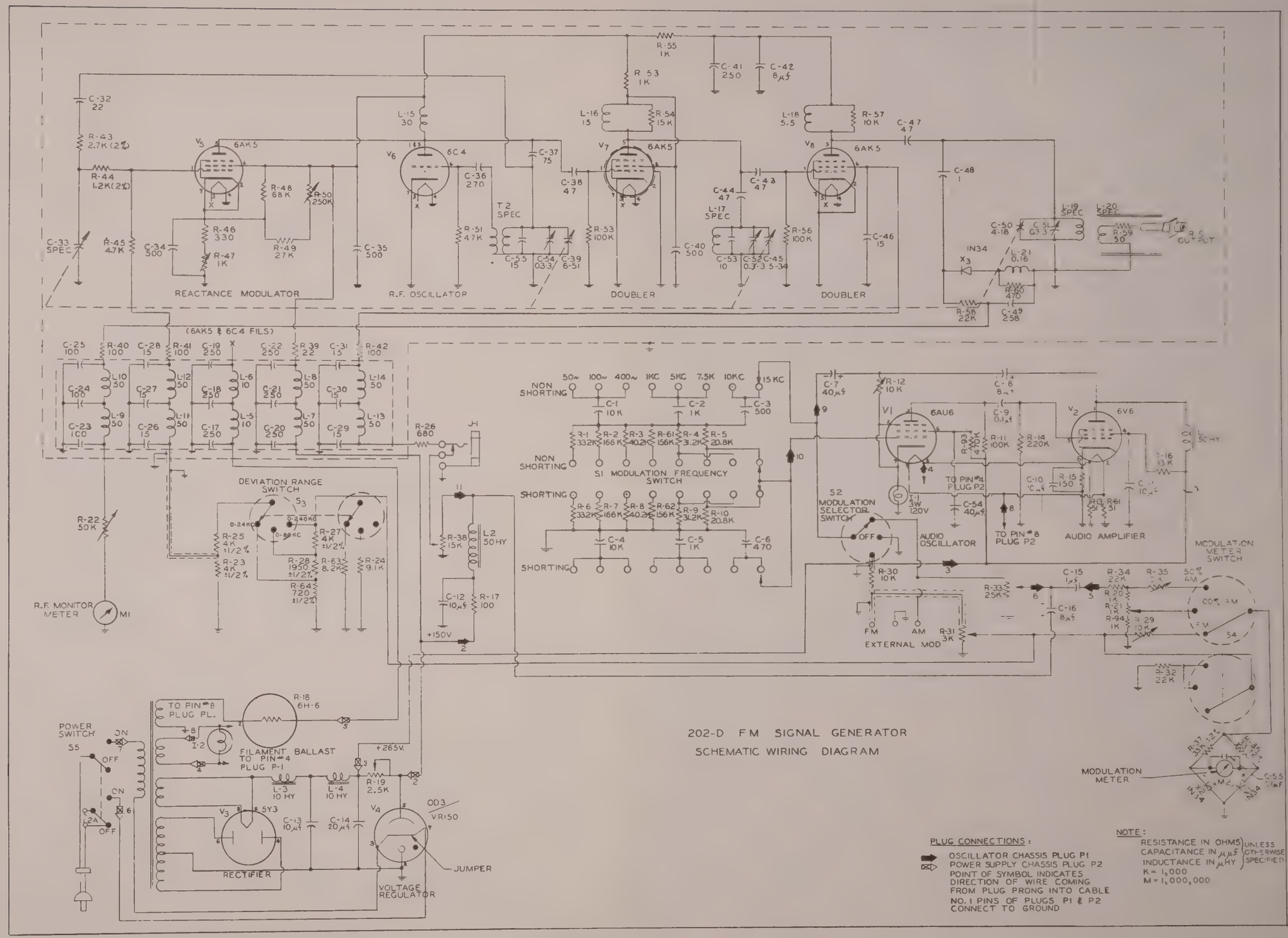


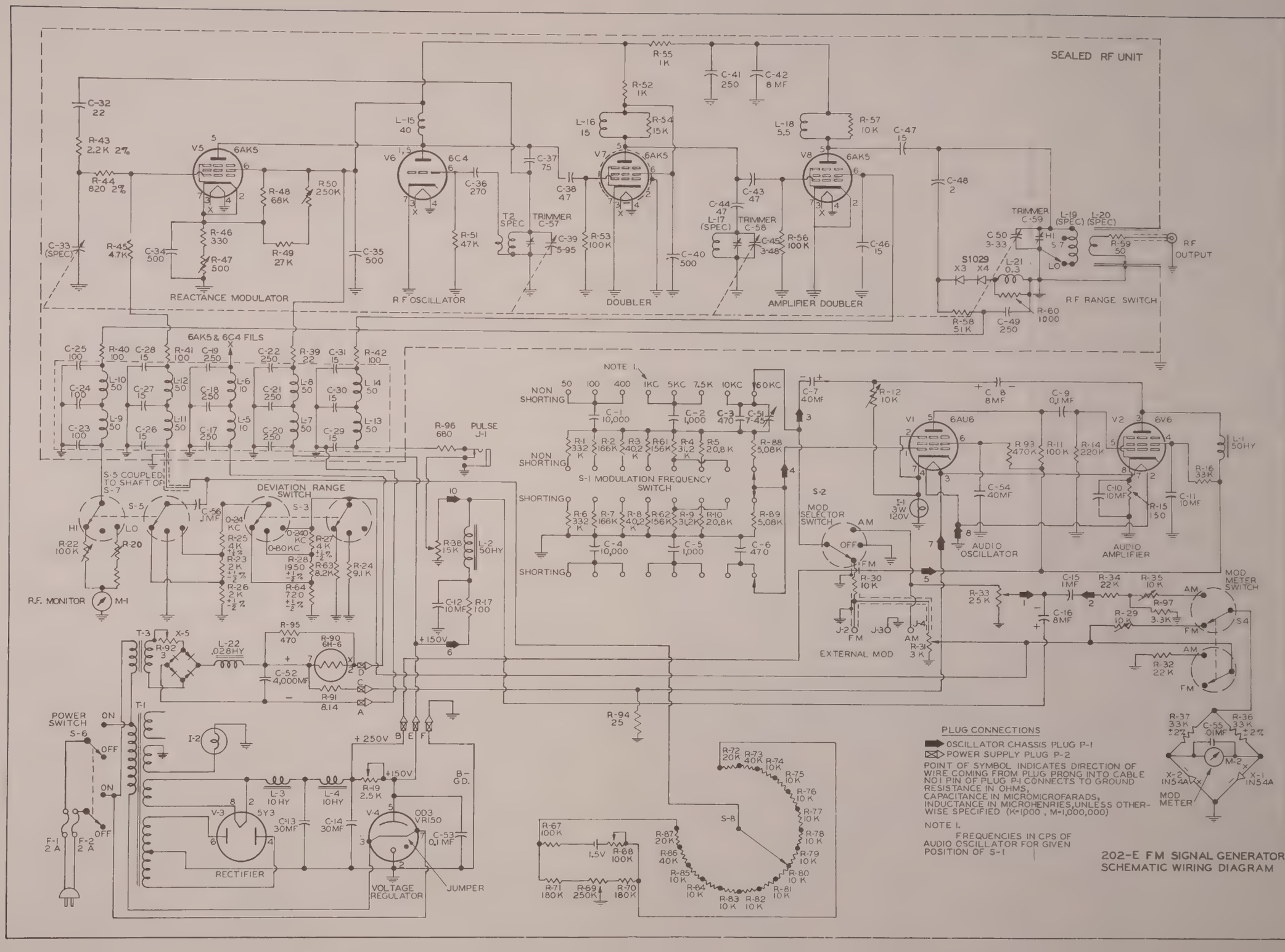
Fig. 8. Schematic Wiring Diagram of 202-B FM Signal Generator



Schematic Wiring Diagram of 202-C FM Signal Generator



Schematic Wiring Diagram of 202-D FM Signal Generator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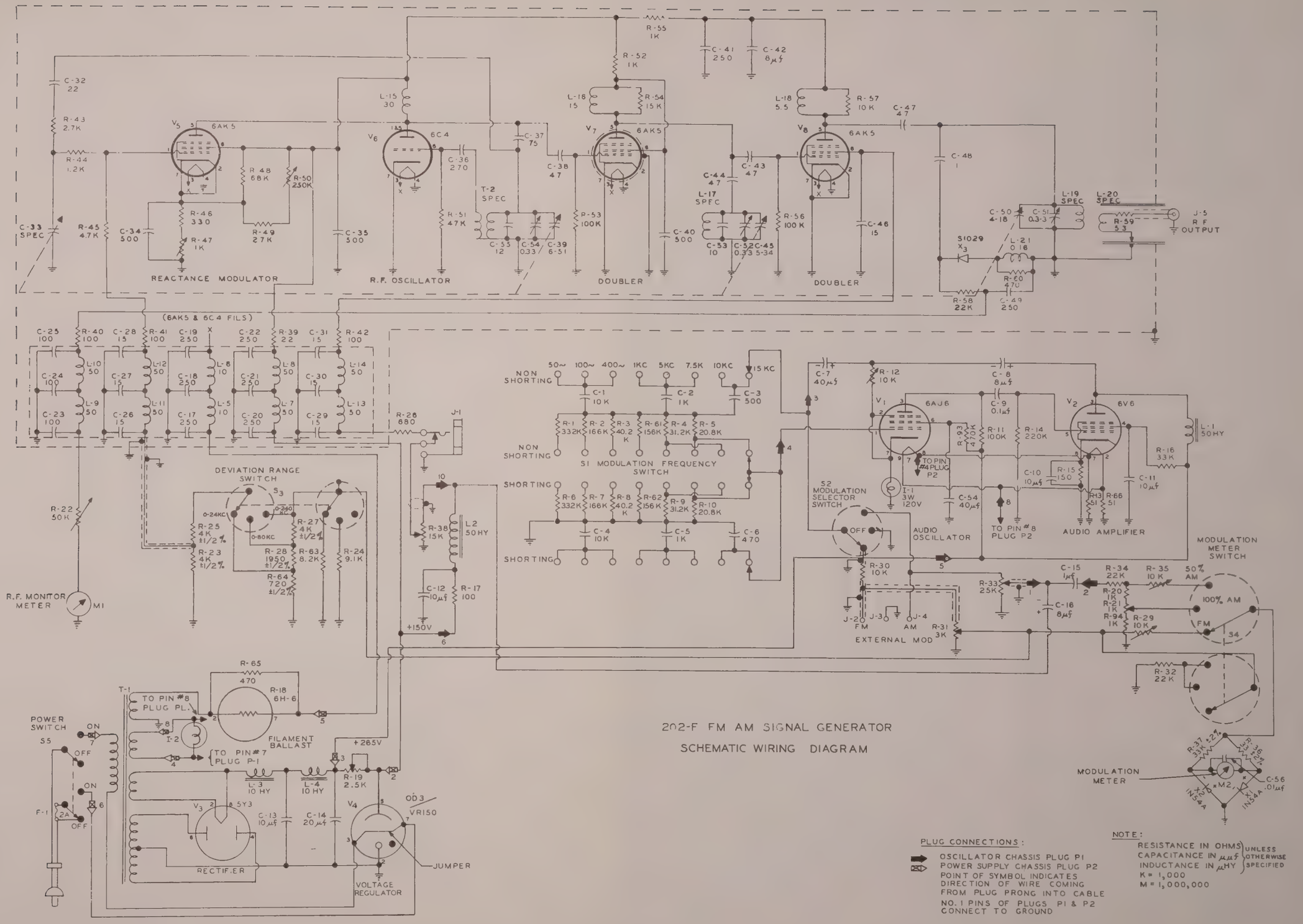
REACTANCE MODULATOR
RF OSCILLATOR
DOUBLER
AMPLIFIER DOUBLER
RF RANGE SWITCH
RF OUTPUT
6AK5 & 6C4 FILS
S-1 MODULATION FREQUENCY SWITCH
NON SHORTING
SHORTING
S-5 COUPLED TO SHAFT OF S-7
DEVIATION RANGE SWITCH
R.F. MONITOR
M-1
PULSE J-1
S-2 MOD SELECTOR SWITCH
AM
FM
OFF
EXTERNAL MOD
AUDIO OSCILLATOR
AUDIO AMPLIFIER
MOD METER SWITCH
POWER SWITCH
RECTIFIER
VOLTAGE REGULATOR
JUMPER
B- GD.
+250V
+150V
PLUG CONNECTIONS
OSCILLATOR CHASSIS PLUG P-1
POWER SUPPLY PLUG P-2
POINT OF SYMBOL INDICATES DIRECTION OF WIRE COMING FROM PLUG PRONG INTO CABLE
NO.1 PIN OF PLUG P-1 CONNECTS TO GROUND
RESISTANCE IN OHMS,
CAPACITANCE IN MICROMICROFARADS,
INDUCTANCE IN MICROHENRIES, UNLESS OTHERWISE SPECIFIED (K=1000, M=1,000,000)
NOTE 1.
FREQUENCIES IN CPS OF AUDIO OSCILLATOR FOR GIVEN POSITION OF S-1
MOD METER
202-E FM SIGNAL GENERATOR
SCHEMATIC WIRING DIAGRAM



202-F FM AM SIGNAL GENERATOR

SCHEMATIC WIRING DIAGRAM

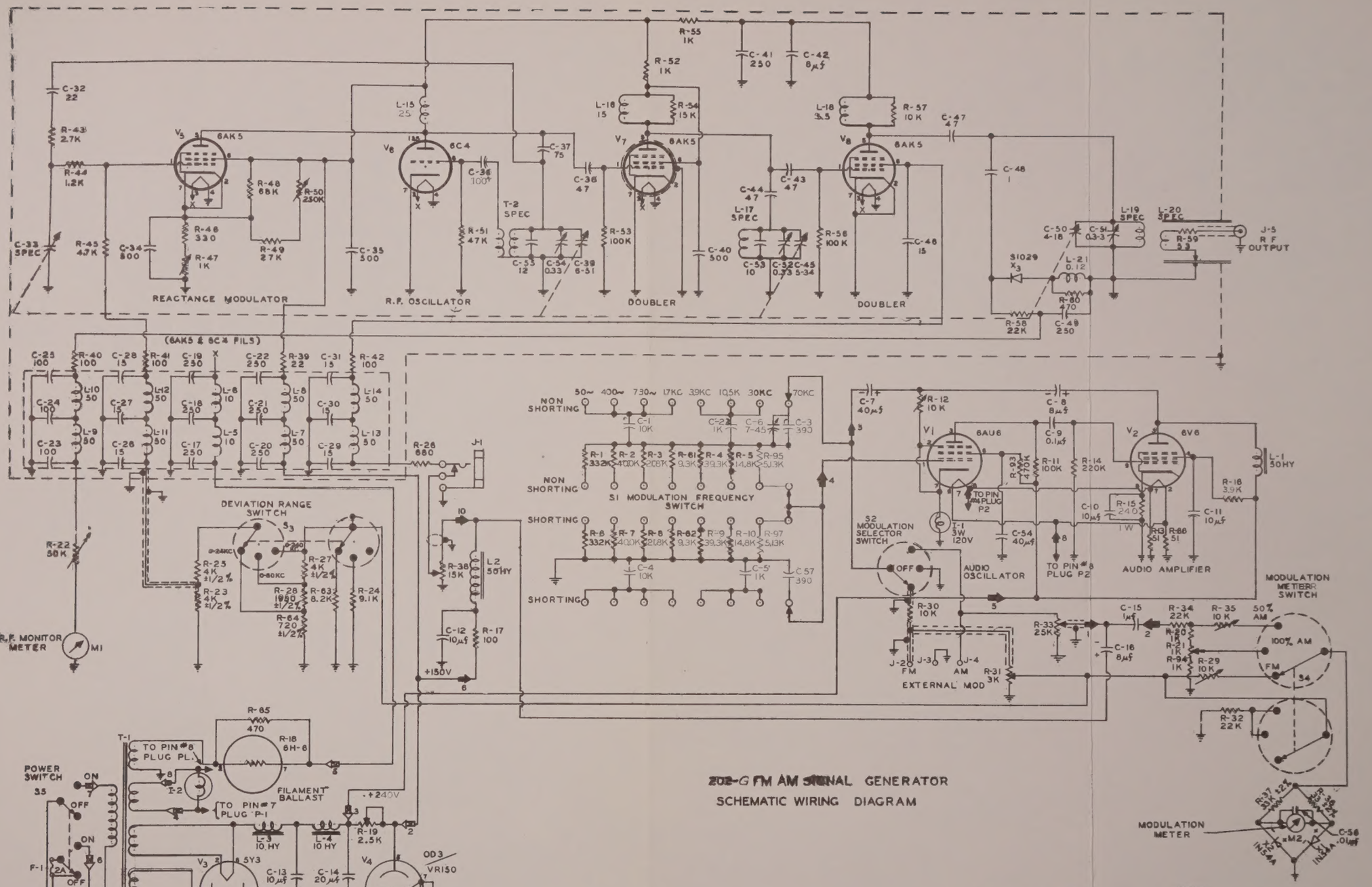
PLUG CONNECTIONS:

- OSCILLATOR CHASSIS PLUG P1
- POWER SUPPLY CHASSIS PLUG P2
- POINT OF SYMBOL INDICATES DIRECTION OF WIRE COMING FROM PLUG PRONG INTO CABLE
- NO. 1 PINS OF PLUGS P1 & P2 CONNECT TO GROUND

NOTE:

RESISTANCE IN OHMS
CAPACITANCE IN μμf
INDUCTANCE IN μHY
} UNLESS OTHERWISE SPECIFIED

K = 1,000
M = 1,000,000


REACTANCE MODULATOR
R.F. OSCILLATOR
DOUBLER
DOUBLER
(6AK5 & 6C4 FILS)
DEVIATION RANGE SWITCH
S3
S1 MODULATION FREQUENCY SWITCH
S2 MODULATION SELECTOR SWITCH
AUDIO OSCILLATOR
AUDIO AMPLIFIER
MODULATION METER SWITCH
EXTERNAL MOD
R.F. MONITOR METER
M1
MODULATION METER
M2
POWER SWITCH
FILAMENT BALLAST
RECTIFIER
VOLTAGE REGULATOR
JUMPER
J-5 R F OUTPUT
202-G FM AM SIGNAL GENERATOR
SCHEMATIC WIRING DIAGRAM
PLUG CONNECTIONS:
OSCILLATOR CHASSIS PLUG P1
POWER SUPPLY CHASSIS PLUG P2
POINT OF SYMBOL INDICATES DIRECTION OF WIRE COMING FROM PLUG PRONG INTO CABLE
NO. 1 PINS OF PLUGS P1 & P2 CONNECT TO GROUND
NOTE:
RESISTANCE IN OHMS
CAPACITANCE IN μμf
INDUCTANCE IN μHY
UNLESS OTHERWISE SPECIFIED
K = 1,000
M = 1,000,000

MP MASTER
MA24309